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THE NATURAL ELECTRIC CURRENTS IN THE EARTH'S CRUST[1]

By O. H. GISH

CHIEF OF THE SECTION OF EXPERIMENTAL WORK IN TERRESTRIAL ELECTRICITY, DEPARTMENT OF TERRESTRIAL MAGNETISM, CARNEGIE INSTITUTION OF WASHINGTON

THAT electricity and magnetism are closely related has been known for more than a century. It is then logical to expect that the forces which direct the compass, terrestrial magnetism, and the electric phenomena of the earth, terrestrial electricity, are also related in some measure and that a knowledge of one may assist in an understanding of the other. Quite appropriately then both these subjects have been from the start included in the program of research of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, with which department the writer has, during the past eight years, been associated in the investigation of terrestrial electricity.

Terrestrial electricity has two natural major subdivisions, namely, atmospheric electricity, in which the electrical condition of the atmosphere is the matter of chief concern, and the electric currents which circulate within the earth.

Electric currents in the earth's crust may arise from a number of sources. That a steady current flows from the air to the earth in ordinary weather is shown by measurements of the electrical condition of the atmosphere. This is so small that an area of 100,000 square miles receives a little less than one ampere. Currents are generated in parts of the earth by chemical processes which take place there. Such currents have been found associated with bodies of some minerals and have been of use in prospecting for them. No doubt small electric currents arise from temperature differences in the earth. Evidence of such has been found in the vicinity of an active volcano. Electric currents are generated when a portion of the earth is set into motion in such a way as to move relative to the earth's magnetic field. Currents generated in this manner by strong tides have been detected. The electric currents developed in the sea by such ocean currents, as, for example, the Gulf Stream, may play a part of some importance to geology, such, for example, as the concentration of metals just as occurs in electroplating. Sudden pulses of electricity arising from lightning discharges and lasting upwards of one thousandth of a second occur at the rate of about 100 per second for the entire earth. Other but less spectacular discharges from the atmosphere to the earth take place during snow-storms, dust-storms, volcanic eruptions, etc., and give rise to corresponding current in the earth. Currents which stray from electric-power systems, especially electric railways, frequently occur in considerable intensity

[1] Lecture delivered at the Carnegie Institution of Washington, April 15, 1930.

in the vicinity of most cities. These are of some economic concern because of the part they play at times in promoting the corrosion of underground steel structures, pipe-lines, etc. They also become a matter of much anxiety to those who have to do with the operation of magnetic observatories, because the magnetic effects which they produce are often much larger than the phenomena of the earth's magnetism which it is sought to study.

The natural electric currents of the earth's crust of which I wish to speak are, however, quite different in character and origin from any of those just mentioned. These currents are generally referred to by the name "earth-currents." However, that term is also applied to the currents which wander from electric railway systems and which as already mentioned constitute a pest in the investigation of the earth's magnetism and to no less an extent in the investigation of the natural earth-currents. The term "vagabond currents" has also been applied to them, quite justly.

The natural earth-currents, or simply earth-currents, were discovered by the effect which they produced on the first long telegraph lines. It was the practice then, as it is now, to complete the telegraph circuit through the earth. In this arrangement, if natural electric currents flow in the earth, they will be shared with the telegraph line. It was soon noticed that the detecting device then used in place of a sounder would sometimes show irregular and violent motions, which were in no way connected with the signals. After a systematic study of these disturbances on a number of different telegraph lines in England, W. H. Barlow in 1847 found that when one line was disturbed, all were disturbed. He concluded that the common source of these occurrences is a natural electric current in the earth's crust. The occasions on which this phenomenon becomes conspicuous on telegraph lines are now referred to as earth-current storms. These earth-current storms constitute at the present time a recurring source of disturbance to telegraph transmission, producing a

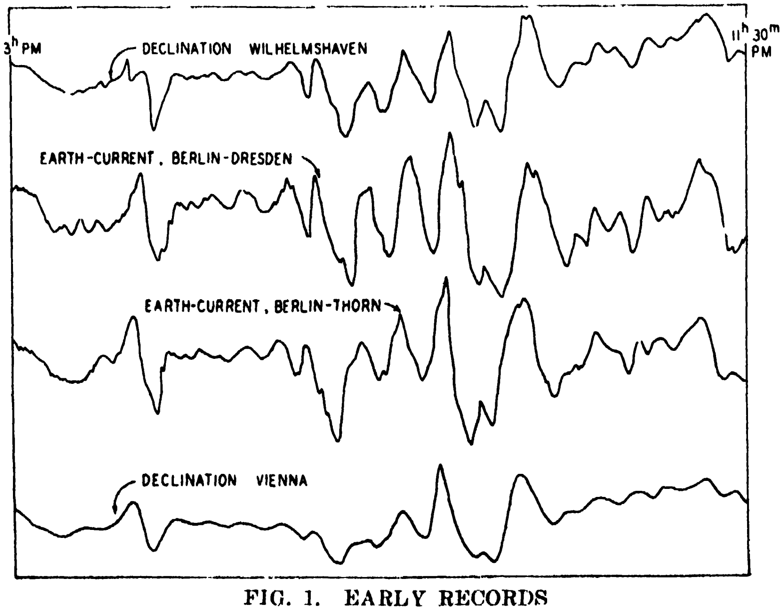


FIG. 1. EARLY RECORDS
OF AN EARTH-CURRENT AND MAGNETIC STORM, NOVEMBER 2, 1884 (AFTER WEINSTEIN).

sort of static and at times injuring the instruments. Although the earth-current which traverses the telegraph line at such times is usually irregular in strength and in direction, yet it is reported on occasions to be sufficiently intense and so steady that messages may be sent without the use of the regular batteries. The earth-current storms are referred to by telegraph operators as "an aurora on the line" Although that appellation implies too much, it has significance The aurora borealis generally becomes visible farther south during the occurrence of an earth-current storm. On these occasions the earth's magnetism also undergoes changes which are referred to as magnetic storms. These magnetic and electric storms are independent of the weather. The curves in Fig. 1 represent changes that occurred in the compass-direction and in the earth-current at from 3 P. M. to 11:30 P. M., November 2, 1884. The upper curve represents changes in the compass-direction at Wilhelmshaven, Germany; the lower those at Vienna, Austria. The two central curves show the earth-current changes on two telegraph lines, one extending from Berlin southward to Dresden, and the other from Berlin eastward to Thorn. The close similarity between the changes in the earth-currents and those in the compass-direction indicates an intimate relationship between these phenomena.

Scientific interest in the phenomena of earth-currents was stimulated by the possibility of finding therein a solution of the age-old problem of terrestrial magnetism. You will recall that Gilbert in the year 1600 published an extensive treatise in which he proposed to account for the earth's magnetism by considering the earth as a large lodestone. At that time the several types of change which occur in the earth's magnetism were unknown. However, Gilbert's theory was brought into question thirty-four years later, when Gellibrand discovered that the compass-direction at London was steadily changing from year to year. Other changes, such as the magnetic storm already mentioned and certain changes which occur in a regular manner during the day, were discovered later. When Oerstedt announced in 1821 the discovery that an electric current gives rise to a magnetic force, this suggested to Sir Humphry Davy the possibility that natural electric currents may flow in the earth's crust and that variation in their intensity may be the direct cause of fluctuations in the compass-direction. A few years later, 1831, Faraday discovered the principle of electromagnetic induction. According to this principle variations in the earth's magnetism should produce electric currents in the earth. Faraday, although unsuccessful in an attempt to detect such currents, remained convinced that they must exist. This presents an alternative to the possibility suggested by Davy, namely, that the changes in the earth's magnetism produce earth-currents. We shall attempt to see the extent to which each of these two possibilities is realized.

The earlier observations of earth-currents were made on telegraph lines and then chiefly at times of disturbance. The chief advance in our knowledge of this phenomenon has, however, come from systematic observations made on lines resembling telegraph lines and especially constructed and suitably located for the purpose. The method employed in measuring earth-currents is shown in Fig. 2. Electrical connection is made with the earth by means of plates of metal buried in the soil. These plates are connected through a suitable measuring instrument by means of a wire or cable which is carried by the poles. The poles are shown arranged along a straight line, but that is indifferent. The current, or more correctly

the electric force, depends only upon the direction and length of the geometrical line joining the plates. If it were possible to have a number of such lines of equal length but extending in all directions from one position it would be found that the electric force, or potential-difference, measured on one of these would be greater at a given instant than that measured on any of the others. The direction of this line would, of course, be the direction of the earth-current. It is not practicable, of course, to have such an arrangement. However, with two lines arranged about as shown in the diagram, the measurements obtained will enable one to calculate the direction of the current. This then is the scheme that is used in obtaining the measurements which disclose the character of these currents and their variations.

Systematic observations with arrangements similar to that just indicated have been made at a number of places; some of the outstanding of these are as follows: at Greenwich Observatory, England, from 1865 to 1867; Berlin, Germany, 1883 to 1891 (in this case underground telegraph cables were used, the one extending from Berlin to Thorn, a distance of 262 kilometers, the other from Berlin to Dresden, 120 kilometers); Parc St. Maur, near Paris, where the system for such measurements was installed in December, 1892, and continued for a period of years, when it was necessary, as was also the case at Greenwich, to abandon the investigations because of the intrusion of vagabond currents from electric railways.

At the present time, such systematic observations are being carried out at three places: the Ebro Observatory, at Tortosa, Spain, at about 41° north latitude, which has been in nearly continuous operation since 1910; and at the two magnetic observatories of the Carnegie Institution of Washington, one located near Watheroo in Western Australia at about 30° south latitude, the other near Huancayo in Peru at about 12° south latitude.[2]

The Ebro Observatory is located in

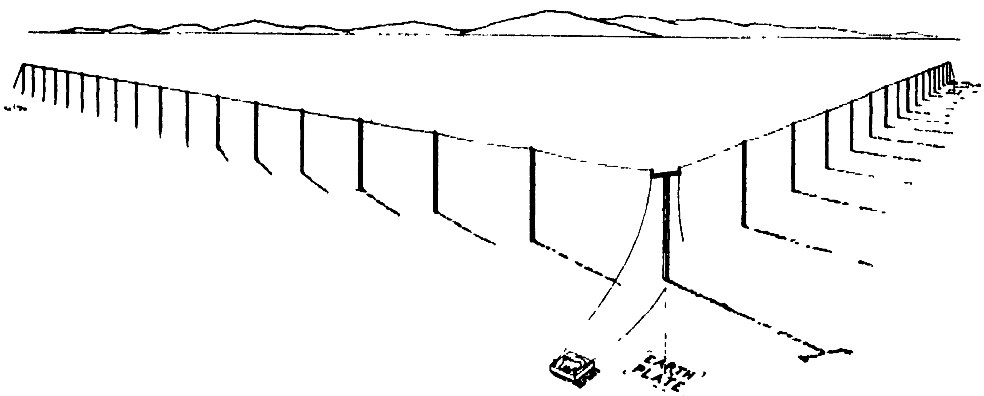


FIG 2. DIAGRAMMATIC REPRESENTATION

OF THE METHOD USED IN MEASURING THE POTENTIAL-DIFFERENCES WHICH CHARACTERIZE EARTH-CURRENTS.

[2] In a letter received after the completion of this paper Mr R. B. Shanck, of the Department of Development and Research of the American Telephone and Telegraph Company, writes that graphic records of the potential-differences on two telegraph-lines of that company running out of New York have been obtained during the past two years. Some records have also been obtained from Swedish telegraph-lines in recent years. It is also learned that observation of earth-currents has been recently begun at Alibag, India.

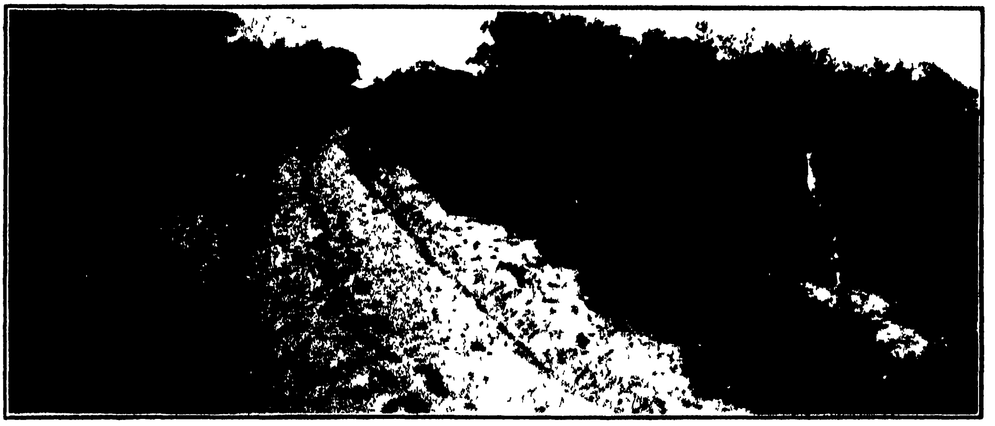


FIG. 3. ROAD FROM WATHEROO TO THE OBSERVATORY
THE SAND IS CHARACTERISTIC OF THIS REGION.

southeastern Spain on the border of the level valley of the River Ebro, near the small town of Tortosa and about 50 kilometers from the Mediterranean Sea. Lines somewhat over one kilometer long are used here. The records from this observatory, obtained under the direction of the Jesuit fathers, constitute the longest, nearly continuous series of earth-current data extant.

The Watheroo Magnetic Observatory is located on a level, sandy plain in Western Australia, about 120 miles north of Perth, 50 miles from the western coast and 12 miles from the Watheroo station. Approaching the observatory from Watheroo (Fig. 3), one gains an impression of the character of the surface and of the wide level expanse of the terrain on which this observatory is located. The registration of earth-currents was started here in November, 1923, and has continued ever since with no important interruption. The standard building (Fig. 4) provided at both observatories for housing the recording instruments used in earth-current and atmospheric-electric investiga-

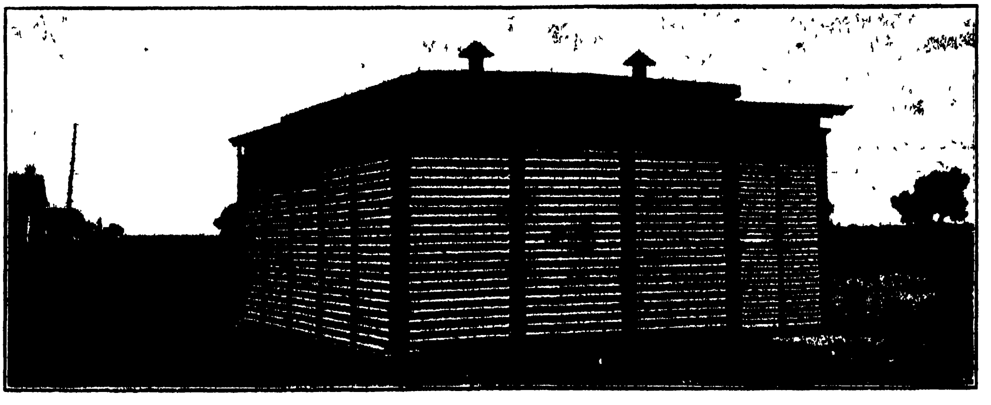


FIG. 4. TYPE OF BUILDING SHELTERING THE INSTRUMENTS
WHICH AUTOMATICALLY RECORD VARIOUS ASPECTS OF TERRESTRIAL ELECTRICITY AT THE OBSERVATORIES OF THE DEPARTMENT OF TERRESTRIAL MAGNETISM OF THE CARNEGIE INSTITUTION OF WASHINGTON.

FIG. 5. LAYING AN UNDERGROUND LINE
AT WATHEROO MAGNETIC OBSERVATORY.

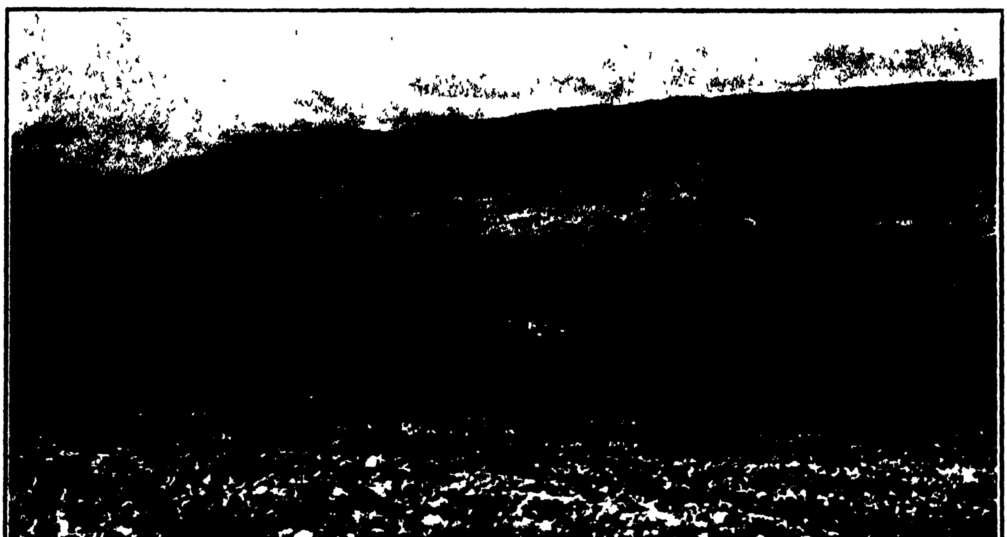


FIG. 6. VIEW OF THE ENVIRONS OF THE HUANCAYO MAGNETIC OBSERVATORY
FROM AN ELEVATION NORTHWEST OF THE OBSERVATORY.

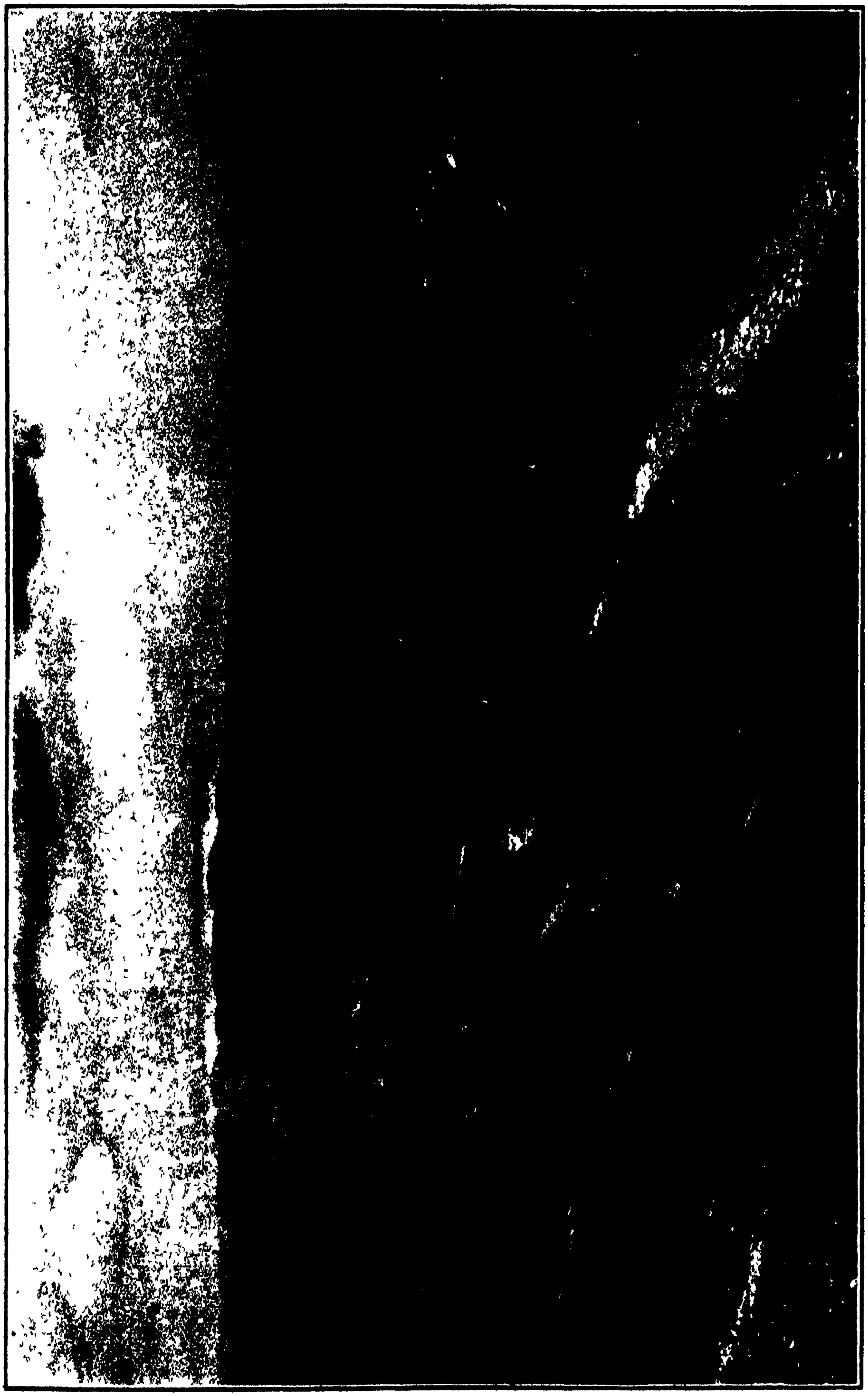


FIG. 7. THE CHUPACO RIVER
AR THE HUANCAYO MAGNETIC OBSERVATORY

tions is a double-walled, concrete structure completely surrounded by a louver. Temperature changes inside this building are small and gradual. The lines used here vary from 1.6 to 10 kilometers in length. A portion of the lines was placed underground in order to ascertain if any appreciable difference occurs between such lines and those placed on poles overhead. The laying of such an underground line is shown in Fig. 5 under the supervision of Dr. G. R. Wait and "Joie."

The Huancayo Magnetic Observatory is uniquely located nearly due south of Washington in the Andes of Peru, at an altitude of 11,000 feet above sea-level. This observatory is also far removed from any industrial sources of disturbance. The site of the observatory lies in a small valley near the confluence of the Chupaco and Montaro Rivers. The observatory appears to the right of the center of the view in Fig. 6. The River Chupaco (Fig. 7) to the west of the observatory is a rapid stream whose bed is cut deep in the general terrain. However, for a considerable expanse about the observatory the topography is quite simple, as will appear in the view in Fig. 8 on approaching the site.

One conclusion coming out of the measurement of earth-currents may be stated at this point, namely, the major part of the earth's magnetic field—the unvarying part—is *not* produced by electric currents in the earth's crust. In all the data available no convincing evidence has been found of the existence of an unchanging component in the earth-current. In other words, the earth-currents are in the main alternating currents, having long periods of alternation. Throughout the following then we will consider only variations in earth-currents, or more correctly, variations in the strength and direction of the force which impels these currents.

This force is very small compared with such electric forces as are a part of our common experience. The force acting between two earth-plates located about 500 miles apart would at undisturbed times be about the same as that which operates your flash-light. At the time of an earth-current storm, however, this force may increase as much as several hundredfold. Some features of a moderate earth-current storm which began at 21 hours Greenwich mean time on July 31, 1929, are shown in Fig. 9. These curves go in pairs The upper of each pair represents the component of the electric force which would impel electricity westward. The lower one indicates that part which acts toward the

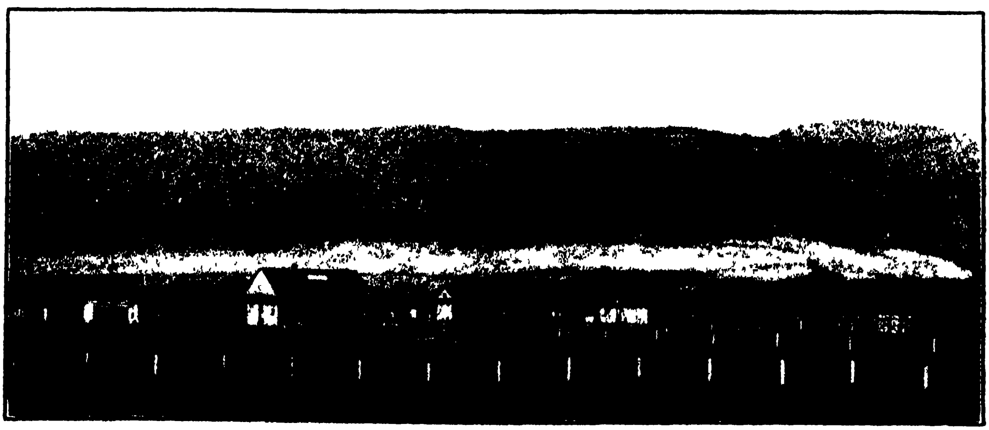


FIG. 8. GENERAL VIEW OF THE HUANCAYO MAGNETIC OBSERVATORY

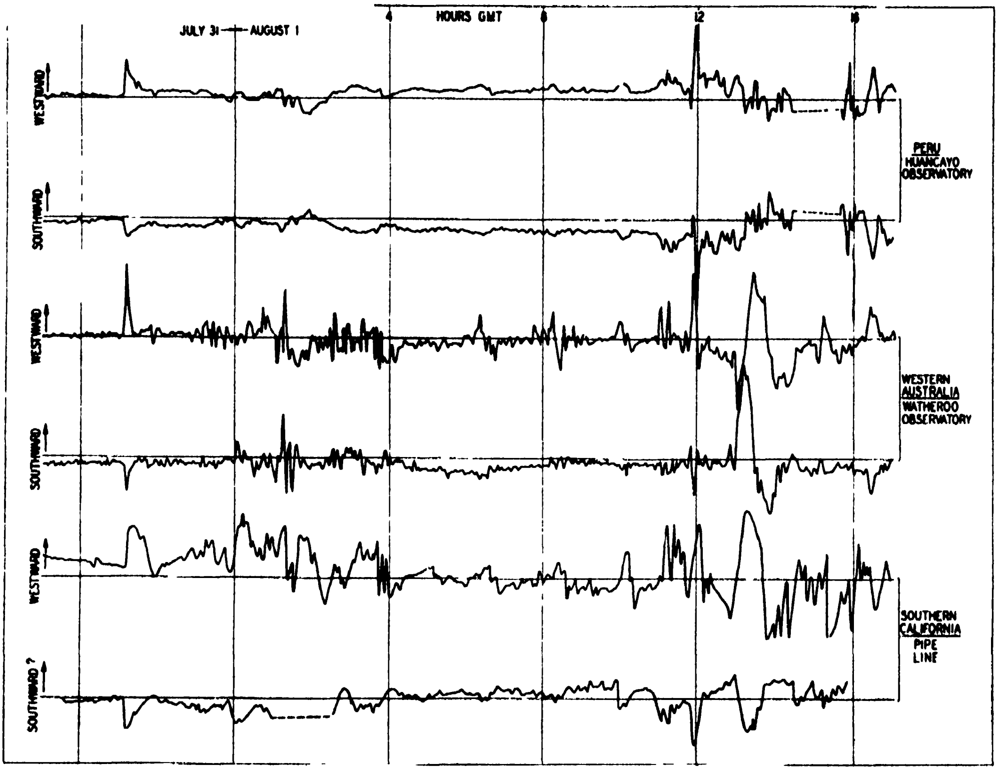


FIG. 9 RECORDS OF EARTH CURRENT STORM
JULY 31 TO AUGUST 1, 1929, AT THREE WIDELY DISTRIBUTED POINTS

southward. The upper pair was registered at the Huancayo Observatory; the middle pair at the Watheroo Observatory, and the lower was transcribed from records of the electric current in an oil pipe-line in southern California. These records were obtained in connection with an investigation of the corrosion of pipe-lines made under the supervision of Mr. K. H. Logan, of the Bureau of Standards, without any intention or expectation of measuring an earth-current storm. One very interesting feature of this exhibit is that the sharp commencement of this storm is not only simultaneous in occurrence at these three widely separated points of the earth but also that the direction of the electric impulse is nearly the same everywhere. Other points of similar agreement throughout may be seen, as well as the general concurrence of dis-

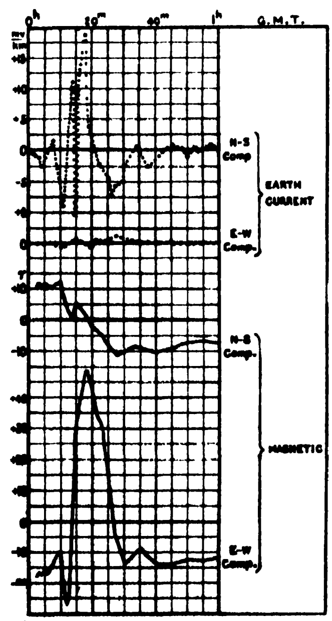


FIG. 10. COMPARISON OF MAGNETIC AND EARTH-CURRENT DISTURBANCES AT WATHEROO.

turbed periods. There can be no doubt but that here is a manifestation of a world-wide process which affects the entire earth at the same instant of time. Aside from the purely scientific interest of this exhibit, it is of importance to investigations of underground corrosion to know the extent to which earth-currents of natural origin, and a part of a world-wide system, may come into play. Magnetic storms also have characteristics similar to those here noted. In fact, earth-current disturbances and magnetic disturbances are so closely related that as an invariable rule they occur in coincidence. An example, observed at Watheroo, is given in Fig. 10. Not all storms, however, have the world-wide characteristic which was displayed by the storm, shown in Fig. 9.

A feature of earth-current storms which is not clearly shown in such diagrams as those just seen is brought out by another method of representation such as is shown in the irregularly shaped diagrams in Fig. 11. The direction and length of each straight-line portion of these diagrams represent the average direction and strength of the changes that occurred in the earth-current in each successive two-minute interval. These diagrams were constructed from observations made by telegraph operators of the American Telephone and Telegraph Company on lines running out from New York City during a storm which occurred on June 17, 1915. Each figure corresponds to a pair of lines whose farther termini are, beginning at the left, Boston and Lansingburg, Lansingburg and Pittsburgh, Pittsburgh and Washington. The approximate direction along which the varying earth-current flows is, at least in temperate zones, in a general north-south direction. This is a matter which is not only of scientific interest, but should be of some importance to the management of telegraph systems, and possibly also in the protection of long pipe-lines from such effects of corrosion as may be promoted by earth-currents.

That the primary source of earth-cur-

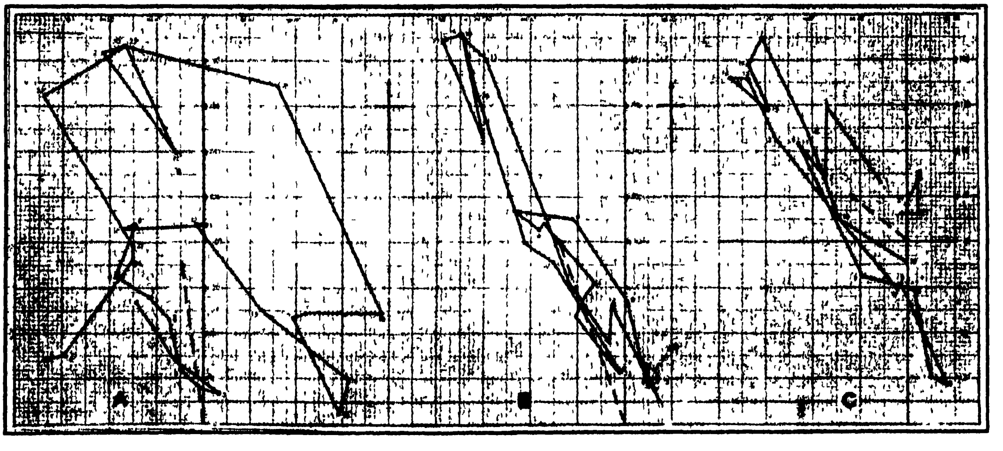


FIG. 11. DIAGRAMS SHOWING THE DIRECTION OF THE EARTH-CURRENT STORM CHANGES AND MEAN VECTORS (DASHED LINES), JUNE 17, 1915, ON LINES OF THE AMERICAN TELEPHONE AND TELEGRAPH COMPANY (HORIZONTAL AND VERTICAL SCALES IN MILLIVOLTS PER KILOMETER; *A*, NEW YORK TO BOSTON AND NEW YORK TO LANSINGBURG, BEGAN AT 16^h 46^m AND ENDED AT 17^h 51^m G. M. T.; *B*, NEW YORK TO LANSINGBURG AND NEW YORK TO PITTSBURGH, BEGAN AT 16^h 56^m AND ENDED AT 17^h 54^m G. M. T.; *C*, NEW YORK TO PITTSBURGH AND NEW YORK TO WASHINGTON, BEGAN AT 17^h 04^m AND ENDED AT 18^h 01^m G. M. T.).

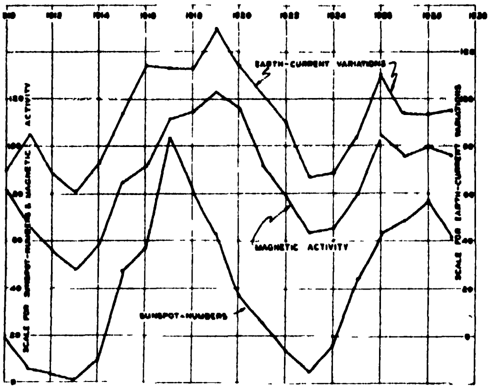


FIG. 12. COMPARISON OF CHANGES IN EARTH-CURRENT VARIATIONS AT EBRO OBSERVATORY, SPAIN, IN MAGNETIC ACTIVITY AT CHELTENHAM OBSERVATORY, UNITED STATES, AND IN SUN-SPOT NUMBERS FROM 1910 TO 1929

rent storms is some factor seated outside the earth and likely in the atmosphere of the sun is indicated by the manner in which the intensity and frequency of these storms change as the sun-spot number (a number designed to give a measure of the total effectiveness of sun-spots) changes. The extent to which the earth-currents, as recorded at the Ebro Observatory, and the earth's magnetism, as recorded at the U. S. Coast and Geodetic Survey Magnetic Observatory at Cheltenham, Maryland, are disturbed and the manner in which this agitation changes from year to year are shown in the two upper curves of Fig. 12. The close similarity of the changes for earth-currents and terrestrial magnetism is not surprising in view of other evidence which has already been seen, but the manner of change from year to year during the twenty years here represented is sufficiently close to that shown in the lower graph for sun-spots that we may consider this as more than a mere coincidence. Another line of evidence which supports this view depends upon the fact that as the sun rotates it carries about with it the sun-spots. Those which are of sufficiently long life will thus appear on the earthward side of the sun at intervals corresponding to the period of rotation of the sun—about 27 days. Hence if some process in the solar atmosphere, which is announced after a fashion by sun-spots, is the cause of the phenomena of earth-current storms, we should expect these storms also to recur with the same period as is found in the case of the sun-spots. The earth-current and magnetic data of the Ebro Observatory were investigated by Peters and Ennis with reference to such a recurrence. The curves shown in the upper part of Fig. 13 present some results of that investigation. These may be interpreted in the following simple manner. If on a certain date, *N*, the range of variation in earth-currents is distinctly larger than that for the days preceding or following, then the range on a date somewhat less than 28 days later will, in the average, be greater than that on the few days preceding or following. A similar recurrence, as will be seen from the middle set of curves, was also found for low values. Furthermore, in the lower part of the diagram, which represents the results of a similar study of the observations of polar lights made on the *Maud* Polar Expedition, 1922 to 1925, will be

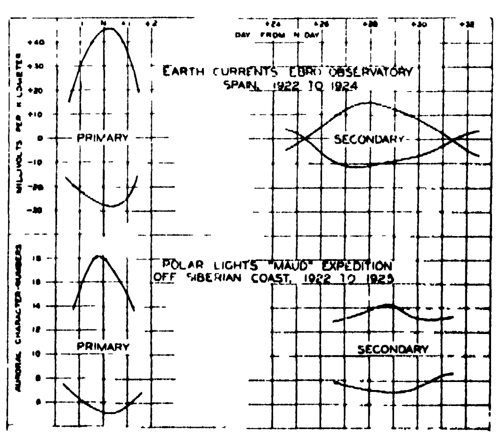


FIG. 13. THE RECURRENCE OF EARTH-CURRENT STORMS AND POLAR LIGHTS IN 27 DAYS.

seen nearly the same type of recurrence in that phenomenon.

Less conspicuous, but no less interesting and important, are variations in earth-currents which proceed in a regular manner throughout the day. These are usually termed diurnal variations. The character of these diurnal variations for the four most extensive sets of modern data available are shown in Figure 14. The two upper graphs apply to the northern hemisphere, namely, Berlin and the Ebro Observatory, and the two lower to the southern hemisphere, namely, the Huancayo Magnetic Observatory and the Watheroo Magnetic Observatory. Although these series do not cover the same period of years, it is not likely that an appreciable difference in the character of the variation represented by these curves would be due to that. A considerable similarity between the curve for Berlin and that for Ebro is evident, and the curve for Watheroo, if reversed, would be very similar to these two. That for Huancayo, however, differs in general type from the other four and at present seems to complicate the general picture. One common feature is that during the daylight hours the currents are more active than at night and that except at Huancayo the northward current is more active than the eastward and flows either away from the equator or towards it, depending upon the time of day. The relative magnitude of the electric force at the several stations is not correctly shown in these curves, it being the purpose here to show the general features of the variation. The forces at the Ebro Observatory are considerably larger than at the other stations. However, from a study of the resistance of the earth to the flow of electricity which has been made at Ebro, Watheroo and Huancayo by W. J. Rooney, as part of the investigations of earth-currents carried on by the Department of Terrestrial Magnetism, it is apparent that the large values recorded at Ebro are in a considerable measure due to the correspondingly

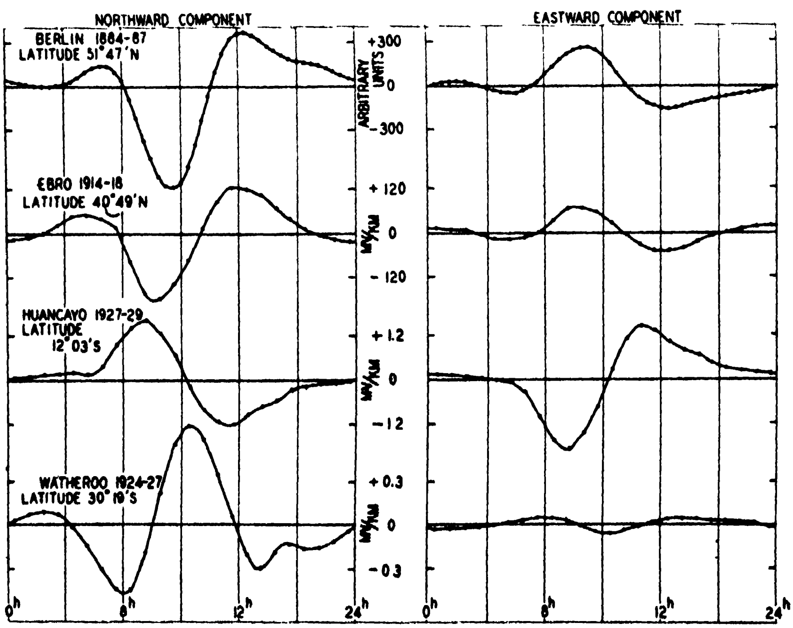


FIG. 14. DIURNAL VARIATION IN EARTH-CURRENT POTENTIALS AT BERLIN IN GERMANY, EBRO OBSERVATORY IN SPAIN, HUANCAYO OBSERVATORY IN PERU AND WATHEROO OBSERVATORY IN WESTERN AUSTRALIA.

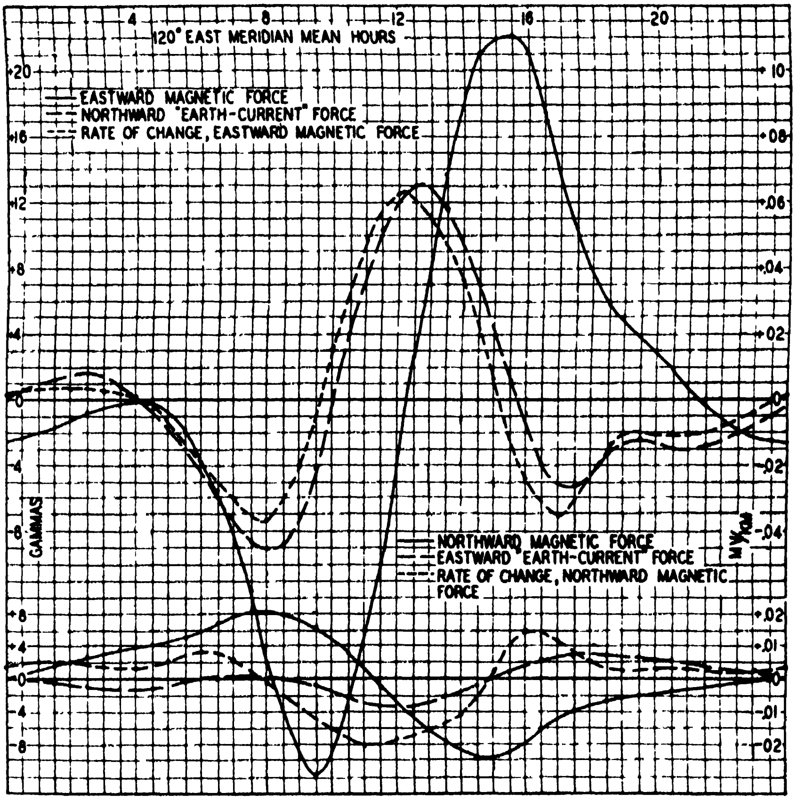


FIG. 15. COMPARISON OF DIURNAL VARIATION

IN EARTH-CURRENTS AND TERRESTRIAL MAGNETISM AT WATHEROO MAGNETIC OBSERVATORY, 1924 TO 1926

large electrical resistance of the earth at that place The branch of study covering this aspect of earth-current investigations can not be entered upon here further than to say that in this work means were developed by which the earth has been explored to depths as great as 600 meters (2,000 feet) by employing electrical measurements made on the surface. This method has aroused much interest among economic geologists and geophysicists.

It is, of course, of interest to see how the diurnal variations in earth-currents compare with the corresponding variations in terrestrial magnetism. In the chart shown in Fig. 15 data from the Watheroo Observatory are thus compared. The solid curve in the upper group represents the diurnal change in the eastward mágnetic force, and that drawn in long dashes represents the corresponding change in the northward-flowing component of the earth-current In the lower group the continuous curve again represents the variation in the magnetic element, this being that component which acts toward the north The curve constructed with the long dash represents the variation in the eastward-flowing component of the earth-current. In neither set of curves is much resemblance to be found between the magnetic and the earth-current changes. The relation thus appears quite different from that seen in the case of storms. If the curve for either magnetic component

and that for the electric component which flows in a direction at right-angles to the former had turned out to be similar, then the possibility that the magnetic changes are produced primarily by the earth-currents could have been considered. This possibility is, however, obviously excluded by this evidence. The alternative which is suggested by Faraday's principle of electromagnetic induction, namely, that the magnetic changes produce the earth-currents, would require that the earth-currents are greatest at the time when the magnetic force is changing most rapidly, disappearing when the magnetic force ceases to change and changing in direction when the magnetic change alters from a decreasing to an increasing force. That these conditions are approximately fulfilled for the upper set of curves is readily seen However, the extent to which this relation exists is shown best by the curves drawn in short dashes. These curves represent the change which should result during the day if the earth-currents arose in the simplest possible way from the magnetic variations. These calculated curves are in much closer agreement with the actual curve than is that for the magnetic variation. However, some disagreement is in evidence, so that it may be unsafe to conclude that the magnetic changes alone are active in producing the earth-current changes It is in fact certain that the earth-currents, even though directly produced by the magnetic changes, will have a reaction which affects the measured values of the earth's magnetic force. The strength of this reaction depends upon the internal structure of the earth, and when the phenomena of earth-currents are more completely known we may hope to use these in exploring the deep structure of the earth.

Conspicuous changes in the amplitude of curves such as those just shown occur from month to month during the year. If the amplitude of these, or the range in the diurnal variation, is charted for each month of the year, the character of this change with season will be best shown. The chief feature in such

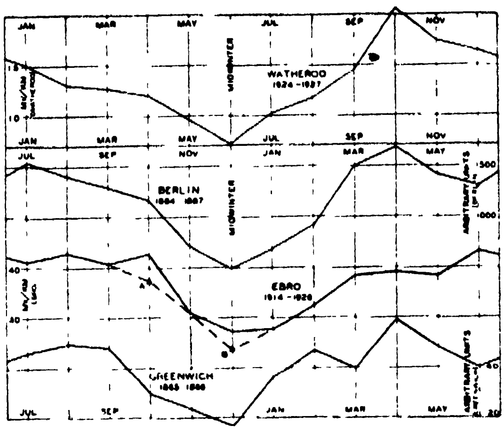


FIG. 16. SEASONAL VARIATION IN DIURNAL RANGE

OF NORTHWARD COMPONENT OF EARTH CURRENTS AT WATHEROO, BERLIN, EBRO AND GREENWICH.

charts (see Fig. 16) is that the lowest values occur at all these observatories at mid-winter and the maximum shortly after the vernal equinox. This variation with season of year suggests that the sun also plays a rôle in the diurnal variation of earth-currents.

You have seen here samples of the evidence which suggest relations between the changes that occur in earth-currents and those that occur in the earth's magnetism, for those irregular changes known as storms, for the diurnal variation, that type of change which occurs in a regular manner during the day, and for the variation from year to year in a cycle corresponding nearly to that of the sun-spots We have also reviewed evidence which shows that some phenomena of both earth-currents and the earth's magnetism are in some way related to the position of the sun and to the occurrence of polar lights. We have noted that in the case of magnetic and earth-current storms the relation is more nearly that which would be ex-

pected if the change in earth-currents were the cause of change in the earth's magnetism, whereas for the changes during the day it would appear more nearly correct to assume that the magnetic changes produce the earth-currents. You will now, no doubt, desire to know what has been done in the way of developing a theory, or perhaps better, a unified picture of these phenomena. In this connection the diurnal variations and the storms should be considered separately. The theories which are offered in explanation of the diurnal variations differ considerably from those suggested for the explanation of the earth-current and magnetic storms. We will first briefly sketch the theory of the diurnal variations. Two theories of this phenomenon are receiving consideration at the present time. Both these theories have the following aspects in common: (*a*) That the process which more directly affects both earth-currents and terrestrial magnetism in a regular manner throughout the day is seated high in the earth's atmosphere; (*b*) that the condition in the atmosphere at this height which makes this process possible is produced by radiations coming from the sun. These radiations acting upon the molecules of this rarefied atmosphere produce electric carriers in extraordinary abundance so that this part of the atmosphere becomes a good conductor of electricity. As to the particular radiation which predominates in producing this effect, there is no general agreement. The ultra-violet light from the sun, or a corpuscular radiation consisting of either positive or negative electrified particles or both, shot from the sun with high speed, and the penetrating or cosmic radiation have been variously considered.

On the one theory, the region of the atmosphere thus capable of transporting electric currents of considerable intensity is subject to great winds. Thus we have a good conductor in motion relative to a magnetic field, namely, that of the earth. In this manner great electric whirls are generated in the high atmosphere. The magnetic effect of these whirls of electricity extends to the earth and induces there earth-currents which in turn give rise to another magnetic effect. The magnetic change measured at the earth's surface, therefore, on this view arises from these two sources, electric currents in the atmosphere and electric currents in earth. The portion of the atmosphere directly under the sun is much more affected than that on the dark side of the earth, and thus as the earth rotates this portion of the atmosphere affects successively the different parts of the earth and can thus obviously give rise to a regular change throughout the day. To account for the winds, however, or the required motion of the high conducting atmosphere presents the great difficulty for this theory. Some evidence that winds of great velocity do exist there is found in the drift of meteor trails

According to the other theory great whirls of electricity in the atmosphere would not occur, but rather, each electric carrier under the action of the earth's magnetism moves in a spiral. This is equivalent to a small magnet. Each electric carrier acts in this way and in a certain orderly fashion, so that without any general electric circulation a magnetic condition arises which at the earth's surface is quite similar to that which would result from the other theory. From this point on, then, the phenomena would proceed in the same way under both theories. The latter theory has the advantage that it is unnecessary to assume the existence of the intense winds required for the former. In this theory, however, a greater abundance of electric carriers is required in the high atmosphere, and it is here that this newer and simpler theory meets its greatest difficulty. Too little is yet known about the constitution of the high atmosphere to be able to firmly establish either of

these theories. However, the present-day development of radio presents a new means of exploring the high atmosphere. It now seems likely that phenomena observed in connection with the transmission of radio waves will provide facts which are needed to decide some disputed points in the theories of the origin of earth-currents and the variations of the earth's magnetism. The common relationship between certain radio phenomena and changes in terrestrial magnetism and earth-currents arises doubtless in part from the fact that this conducting region of the atmosphere has a common influence on all these phenomena, so that a study of each will assist in the understanding of the others.

Whatever the reality underlying the diurnal variations may be, the theories just outlined at least serve as a sort of aid to the memory by providing a visualization of these phenomena for the earth as a whole. The system of currents which J. Bartels, of Germany, has calculated would be required in the atmosphere to produce the observed diurnal changes in the earth's magnetism is shown in Fig. 17. The arrowheads and the course of the curves indicate the path of the current, and the concentration of the curves represents the density of the current. Over the sunlit hemisphere two great whirls will be seen, one on either side of the equator. These are of greater regularity and density than the circulations shown over the other hemisphere. The total current estimated for one of the daytime whirls is 100,000 amperes. This diagram will serve also to give a picture of the general character of the system of currents in the earth's crust at ordinary undisturbed times.

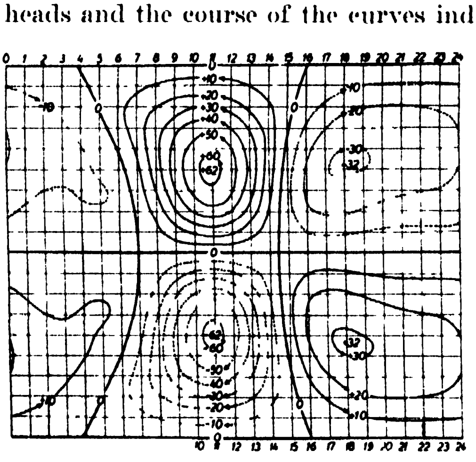


FIG. 17. THE SYSTEM OF ELECTRIC CURRENTS

WHICH ACCORDING TO ANALYSES OF BARTELS AND CHAPMAN, WOULD BE REQUIRED IN THE HIGH ATMOSPHERE TO PRODUCE THE AVERAGE DIURNAL CHANGES IN THE EARTH'S MAGNETISM.

Earth-current storms and magnetic storms should, in view of the close relationship shown by many observations, find a common explanation. Various attempts have been made to provide a theory or some model which would account for magnetic storms, but in these the phenomena of earth-current storms have been generally neglected from consideration. The result of this one-sided development is that all theories of magnetic storms fail to account for the principal phenomena of earth-current storms, and until they do, they can scarcely be considered seriously, even should they satisfactorily account for all the principal phenomena of magnetic storms, which they do not. All the recent theories of magnetic storms invoke electric currents which are assumed to arise in the atmosphere high above the earth, currents which depend upon processes seated in the atmosphere of the sun. As to the manner in which these currents are produced, there are three views extant. The corpuscular theory holds that streams of electrons shot from the sun at speeds nearly that of light, under the action of the constant part of the earth's magnetic force, are in part caused to converge in a zone near the magnetic poles and are in part made to encircle the earth in the rare atmosphere high above the equatorial belt. The former give rise to polar lights and some magnetic impulses, and the latter constitute

the direct source of the major aspects of magnetic storms.

The induction-theory assumes that the high atmosphere is subject to a complicated system of winds or circulation which, if that region of the atmosphere be a sufficiently good conductor of electricity, will generate electric currents there because of the motion of this conductor relative to the earth's magnetic field Both the winds and the conductivity in that part of the high atmosphere which comes into consideration here may vary suddenly under the action of radiations from outbursts on the sun, radiations which both heat the atmosphere and increase the number of electric carriers there. The sudden changes in the currents thus produced would in turn cause magnetic changes at the earth's surface

In yet another very recently proposed theory the somewhat forced assumptions which appear in the two older theories, namely, the high-speed electric corpuscles and the complicated system of winds, are replaced by devices which appear more plausible. In this, reasons are given which make it seem likely that by the action of the ultra-violet light from the sun some atoms are blasted from the portion of the atmosphere located about 450 kilometers from the earth and are carried thousands of kilometers farther out before they are ionized. When ionized, the earth's magnetic force combined with the force of gravity tends to cause these to circulate about the earth's axis, especially over the equatorial belt, thus producing in turn a magnetic change at the earth's surface corresponding to the world-wide magnetic-storm effect. Some, however, drift along the magnetic lines of force and return to lower levels near the poles where they give rise to other aspects of magnetic storms and produce the polar lights. Relatively large changes occur in the intensity of the ultra-violet light emitted by the sun and thus give rise to the irregular fluctuations recorded in magnetic instruments. This theory has very attractive features but many details require further study In all these theories the world-wide part of a magnetic storm is considered as caused by electric currents in the high atmosphere over the equator. This would require that the electric currents in the earth's crust flow in an east-west direction at such times, especially in lower latitudes, but so far as observations go these currents tend rather to flow in a north-south direction, as has already been seen in Fig 11. Another point of disagreement between theory and fact is that the time relationship between the earth-current changes and the magnetic changes, as noted earlier in this discussion, is that which should be found if the former were the cause and the latter the effect.

At the present stage of our studies, it appears that many of the magnetic changes which occur at storm times are produced by the earth-currents, that in general the currents characteristic of storms flow, roughly speaking, either north or south and at least in some cases traverse the earth, roughly speaking, from pole to pole, as though electricity were supplied at one pole and removed at the other. There are, however, grave difficulties in the way of such a view. The solution of the riddle presented by earth-current and magnetic storms will doubtless be furthered by more intensive study and observation of earth-currents and especially by observations in the far north (or south). Do the splendors of the polar lights signalize a terrific bombardment of the polar atmosphere by electric particles traveling at a speed sometimes so great that this bombardment reaches the earth and thus by supplying electricity in an irregular manner give rise to earth-currents at times of storm? This is one of the questions which we hope further studies of earth-currents will assist in answering.

PROBLEMS OF ANTIQUITY PRESENTED IN GYPSUM CAVE, NEVADA[1]

By Dr. CHESTER STOCK

BALCH GRADUATE SCHOOL OF THE GEOLOGICAL SCIENCES, CALIFORNIA INSTITUTE OF TECHNOLOGY

Introduction

Strikingly real as the material evidence of the life record of the past frequently is the vividness of that reality is in large measure dependent upon the satisfaction which one experiences in apprehending organisms of a remote period as once living creatures. Nowhere is this better exemplified than in those noteworthy occurrences where remains of mammalian types, presumably long extinct, have come down through time, exhibiting not only skeletal parts but also the epidermal structures, excrement and occasionally the viscera in a remarkable state of preservation. Curious though it may seem our views regarding the geologic antiquity of this type of material are frequently but dimly defined.

It is now a little over thirty years since the Swedish explorer Nordenskjöld, learning of the discovery of a curious piece of hide near Last Hope Inlet, Patagonia, was led to investigate the famous Eberhardt Cave of Ultima Esperanza. Excavations in the deposits by Nordenskjöld, Moreno, Erland Nordenskiöld and others brought to light an unusual collection of material including remains of man and of several types of extinct

[1] Based on a paper presented before the National Academy of Sciences, Pasadena, September 23, 1930.

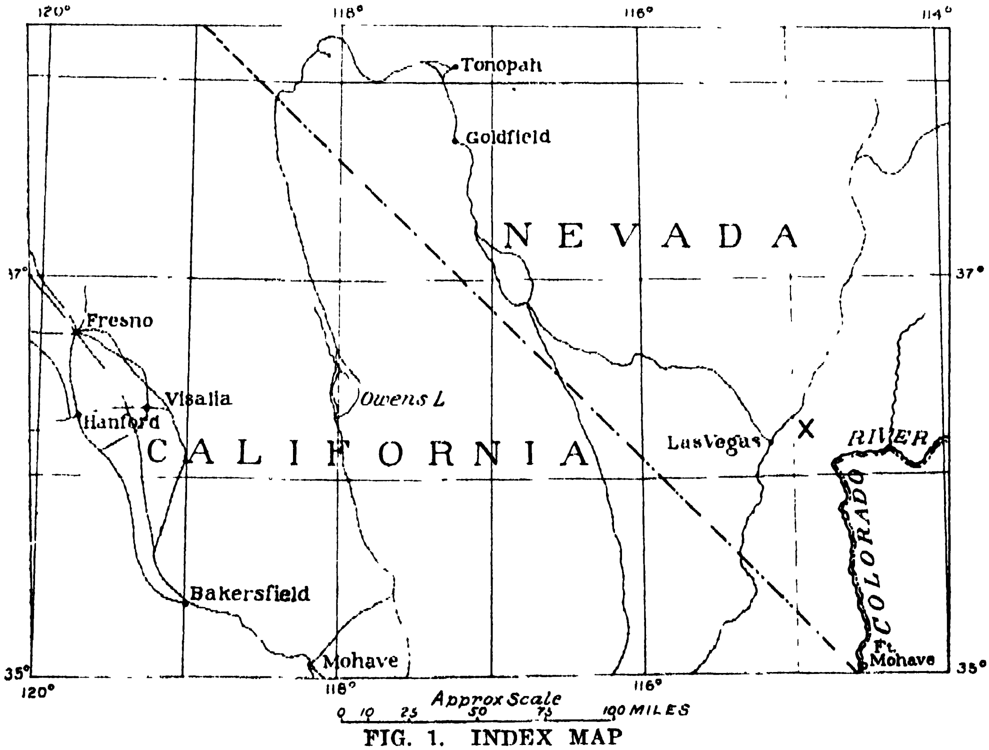


FIG. 1. INDEX MAP

SHOWING LOCATION (×) OF GYPSUM CAVE, NEVADA.

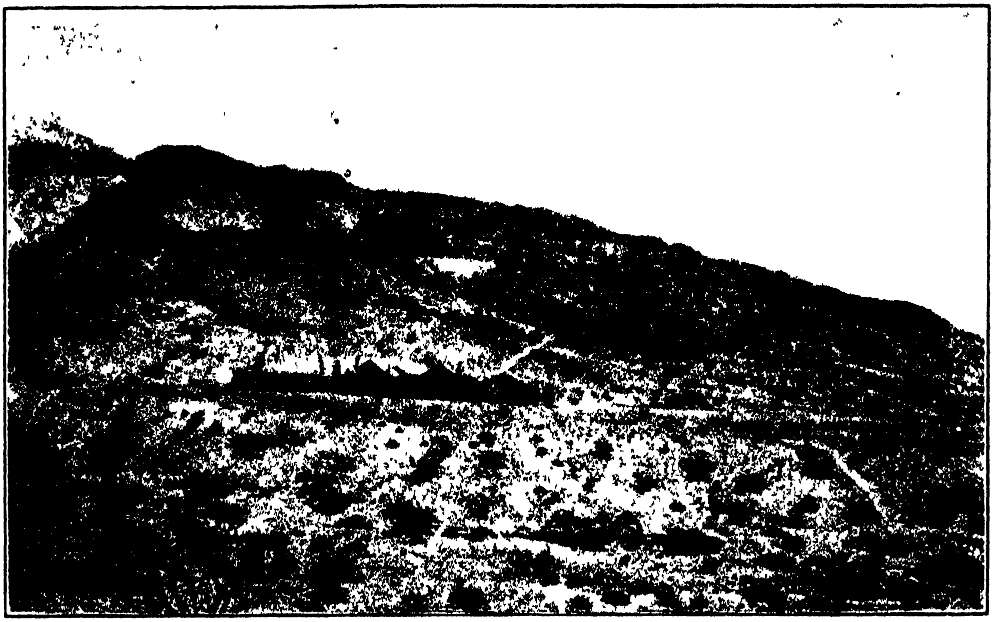


FIG. 2. VIEW LOOKING NORTHEAST

SHOWING ENTRANCE TO GYPSUM CAVE AT BASE OF LIMESTONE FACE (IN SHADOW) ABOVE CAMP OF SOUTHWEST MUSEUM-CALIFORNIA INSTITUTE. THE SPARSE VEGETATION IN FOREGROUND INCLUDES SEVERAL SPECIES OF CACTI, CREOSOTE BUSH, *Krameria*, CATCLAW AND NEEDLE GRASS.

mammals. Among the specimens were fragments of skin, hair, horny sheaths of claws and excrement found definitely associated with skeletal remains of large mammals. The materials, exhibiting characters totally unlike those of any living animal of South America, were later determined to be of the extinct ground sloth *Glossotherium*.

So real did the ground sloths become in view of the remarkable preservation of their remains that the story of an actual existence of these animals—the mysterious mammal of Patagonia—was received with considerable credence. Later explorations in South America failed to substantiate the story, but the facts concerning the occurrence and associations of *Glossotherium* are regarded by many as furnishing at Ultima Esperanza indisputable evidence of the presence of man and of mammals generally regarded as characteristic of the Pleistocene or Ice Age.

The recent discovery of Gypsum Cave in southern Nevada by Mr. M. R. Harrington, of the Southwest Museum, brings to light a cavern occurrence and an entombed life record presenting many features similar to those which characterize the South American cave. Located in the foothills of Frenchman Mountain, by road 20 miles east and slightly north of Las Vegas, this cave is readily accessible at an elevation of approximately 2,000 feet. Deriving its name from the presence of huge and beautifully formed selenite crystals, Gypsum Cave has resulted from differential solution in Paleozoic limestone and is now of large size and of irregular shape (see Fig. 4).

The presence of several cultural stages and the unusual preservation of an animal and plant record in the deposits furnish an almost unprecedented opportunity for the archeologist and paleontologist. At the invitation of the South-

west Museum the California Institute has been fortunate in sharing equally in the investigation of the site, concerning itself particularly with the stratigraphic succession and with the interpretation of the fossil or subfossil animal and plant remains. While the recent explorations have not been completed certain striking aspects of the deposits and of the specimens recovered are worthy of delineation as furnishing perhaps a typical example of the problems encountered in broader studies of the succession of Quaternary life in America.

cave. Situated 65 feet below the entrance to the cavern, this chamber is approximately 120 feet long by 65 feet wide (Fig. 7). Entrance to it is gained toward the bottom of a broad, inclined surface of angular limestone rubble.

At a depth of 14 feet large limestone blocks were encountered. It is possible that these represent the rock floor on which the sediments accumulated. The strata above this consist principally of angular limestone fragments, the individual fragments frequently being a fraction of an inch in diameter. Much

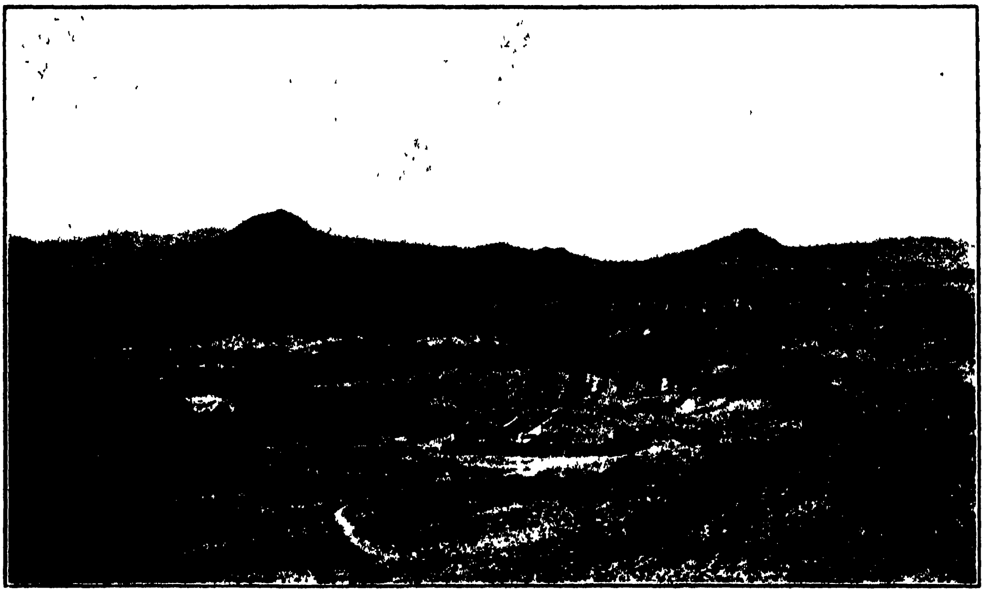


FIG. 3. VIEW LOOKING SOUTHWEST FROM CAVE ENTRANCE

SHOWING DESERT COUNTRY EAST OF FRENCHMAN MOUNTAIN, NEVADA. GYP PEAK IN DISTANCE TO THE LEFT OF FIELD CAMP OF THE SOUTHWEST MUSEUM-CALIFORNIA INSTITUTE.

Deposits

While each of the several more or less clearly outlined chambers of the cave exhibits an interesting stratigraphic record, perhaps the clearest cross-section of the deposits is that revealed beneath the floor of the principal chamber (Room 4). Doubtless the sedimentary succession shown here by trenching furnishes an important key to the interpretation of the deposits found elsewhere in the cave.

of the material may have been derived from the walls and ceiling of the cavern. Intercalated in the series are irregularly bedded sands, doubtless deposited under water. At the top of the deposit of fragmental limestone occurs a gypsiferous layer followed upward by sloth dung. The latter exhibits in places a matted and trampled appearance; in others the individual clods retain for the most part their original form. Occa-

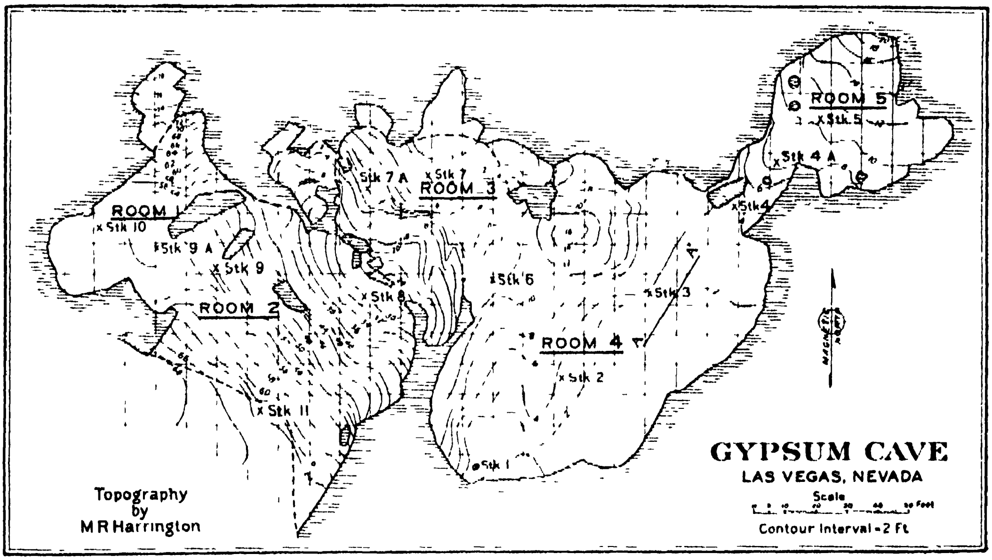


FIG. 4. TOPOGRAPHIC MAP OF GYPSUM CAVE

A A′, LOCATION OF SECTION THROUGH UPPER DEPOSITS IN ROOM 4.

sionally specimens are found in which the outer shell of a clod remains intact but the inside has been consumed, perhaps by rodents. In places also the dung is burned or charred while elsewhere it has a remarkably fresh appearance. Scattered through this accumulation is the dung of other mammals. The layer of dung has a maximum thickness of at least 26 inches, although laterally it may thin to a few inches. Intercalated in it may be found a second gypsiferous layer, usually a few inches thick. At several localities stalagmites have formed, and it is interesting to note that where these are found the dung is absent.

Piled on the floor in Room 4 is a large mass of limestone débris derived presumably in part from the ceiling as a rock fall and in part from rock slides. Evidence obtained from the depositional record would appear to indicate that slide or fall material accumulated also during the formation of the dung layer. The extent and distribution of the dung material suggests, moreover, that the animals responsible for its accumulation had ready access to this portion of the cavern and were represented by a number of individuals or frequented the chamber for a long period of time.

A well-defined dung layer has been recorded by Harrington as occurring also in Room 1, immediately to the left of the entrance to the cave. It is a fair assumption perhaps that the period of accumulation of the material in this

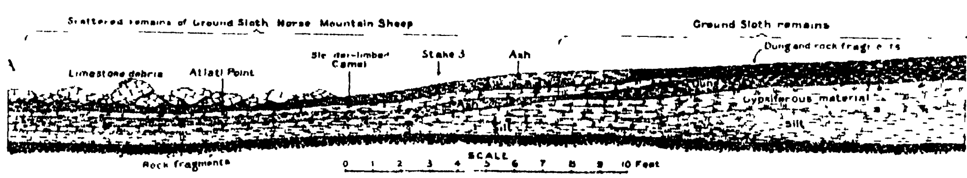


FIG 5. CROSS-SECTION OF UPPER DEPOSITS

AT A–A′, IN ROOM 4, SHOWING POSITION OF ATLATL DART-POINT AND BONES OF EXTINCT MAMMALS. FROM FIELD SKETCH BY J. E. THURSTON. GYPSUM CAVE, NEVADA.

FIG. 6. VIEW LOOKING ACROSS LOWER END OF ROOM 2

ENTRANCE TO ROOM 4 IS LOCATED OFF LOWER RIGHT HAND CORNER OF PICTURE. GYPSUM CAVE, NEVADA.

chamber coincides with that of dung formation in Room 4. Considerable sheep manure is found toward the top of this layer. Above it occurs limestone detritus to a thickness of six or more feet, followed in turn upward by a layer from which Pueblo and Basket-maker cultures have been obtained.

SOME ORGANIC REMAINS FOUND IN THE DEPOSITS

Mammalian remains have been encountered in the lower strata which have been penetrated in Room 4. In the sands intercalated in the deposit of angular limestone fragments at a depth of ten feet were found incomplete skeletal elements and teeth of camel and horse. Thus far, however, the ground sloth remains are not known to occur below the overlying dung layer. The latter is in large part made up of the excrement of the ground sloth *Nothrotherium*. A well-preserved specimen of this material is shown in Fig. 9. Superficially these clods are like the excreta of the South American genus *Glossotherium*, figured by Santiago Roth (compare Figs. 8 and 9), although the former are somewhat smaller in size.

No attempt has been made as yet to identify all the plant remains which constitute the bulk of the clods and of the trampled manure in Gypsum Cave. The scatological studies will furnish valuable information concerning the food habits of the nothrotheres and it is to be hoped also of the floral environment which prevailed in the vicinity of the cave during the period of existence of these animals

The better preserved skeletal and epidermal structures of these ground sloths occur in the dung layer. No complete skeleton of *Nothrotherium* has been found, but a number of elements have been recovered. It is significant that most of the skeletal remains belong to this ground sloth. Fig. 10 shows a nearly complete hind foot of *Nothrotherium* in which several of the bones exhibit on the surface bits of dried flesh or tendinal strands. Moreover, the

horny claws of the terminal phalanges remain intact. Small fragments of the hide appear to be also preserved. This material is now thoroughly desiccated and shrunken, but reveals on the surface occasionally the base of many hairs. There is no evidence of the presence of ossicles in the skin as in the mylodont ground sloth *Glossotherium* of Eberhardt Cavern. Many strands and occasionally small masses of hair have been found in Gypsum Cave. These frequently have a yellow or tawny color, although hair of a brownish or reddish brown color has been noted. Whether all the hair found thus far belongs to *Nothrotherium* has not been determined

While the skeleton of *Nothrotherium* has been known by rather complete remains described from the Brazilian caves and from the asphalt deposits of Rancho La Brea in California, only recently has direct information become available regarding some of the external characters of this creature. Professor Lull has described[2] an unusually complete skeleton with remains of epidermal structures and a food ball from a guano deposit at Aden Crater, New Mexico.

A native of the southern continent, *Nothrotherium* reached North America apparently during Pleistocene time. Closely related types occur in middle or lower Pliocene deposits of western North America, and it is possible that the nothrotheres were among the first mammals to arrive from South America when the two areas were joined, after a prolonged separation, in late Tertiary time. An illustration of the skeleton of *Nothrotherium* is shown in Fig. 11.

Skeletal remains of at least three additional mammals of relatively large size occur in the dung deposit It is not surprising to find the mountain sheep (*Ovis*) recorded in view of the frequent occurrence of sheep dung. The presence of a slender-limbed camel is indicated by several broken skeletal elements This type differs in structural characters from the large camel (*Camelops*) recorded at Rancho La Brea and may be closely related to a slender-limbed camel (*Tanupolama*) described from the Mc-

[2] R. S. Lull, *Mem. Peabody Mus. Yale Univ*, Vol. 3, pt 2, 1929

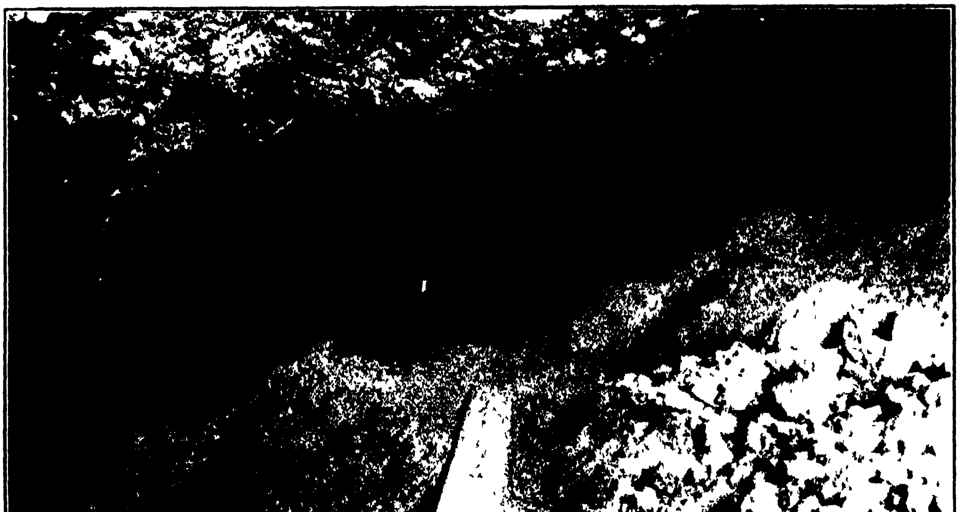


FIG. 7. VIEW OF ROOM 4

FROM POINT AT ENTRANCE TO ROOM 5. SLOTH DUNG LAYER WITH BONES OF EXTINCT MAMMALS EXPOSED IN TRENCH ON LEFT; LIMESTONE DÉBRIS ON RIGHT. GYPSUM CAVE, NEVADA.

FIG. 8. GROUND SLOTH AND ASSOCIATED REMAINS

FROM EBERHARDT CAVERN, LAST HOPE INLET, PATAGONIA. FIGS. *a, e, f, g*, SKIN AND EXCREMENT OF GROUND SLOTH *Glossotherium*. APPROXIMATELY × ⅛. AFTER SANTIAGO ROTH.

FIG. 9 DUNG OF EXTINCT GROUND SLOTH *NOTHROTHERIUM*

Approximately × ⅓ Note plant remains and dried mucous covering Gypsum Cave, Nevada.

Problems

Two problems of major importance are presented by the Gypsum Cave occurrence, namely:

(1) Was man coexistent with some or all of the animals occurring in the deposits?

(2) What degree of antiquity in Quaternary time can be ascribed to the mammalian fauna and more particularly to those types found in the dung layer?

A consideration of the first question involves a critical analysis of the evidence furnished by artifacts present in the deposits and by the stratigraphic relationships of the human cultural stages to the occurrence of extinct mammals. The archeologist, seeking to extend the early history of man in Amer-

FIG. 10. RIGHT HIND FOOT OF *NOTHROTHERIUM*

View from above, approximately × ⅓ Note presence of horny sheaths on claws. Gypsum Cave, Nevada.

Kittrick deposits, a second asphalt accumulation of Quaternary age in California.

The relationships of the fourth type to be mentioned, namely the horse (*Equus*), have not been definitely determined particularly with reference to the known species of horses from the Pleistocene of western North America Materials found in the dung include not only skeletal parts but portions of the horny hoofs as well.

No evidence has appeared as yet indicating the presence of the larger and more formidable types of carnivores known to have existed in Pleistocene time. While the smaller predatory forms are represented by skull and skeletal materials in the collections, the great lion, the saber-tooth cat, the short-faced bear and the dire wolf remain unrecorded.

ica, is fortunate in finding at Gypsum Cave material evidence of past cultures and of extinct animals as well as a sequence in the stratigraphic occurrence of this material. Thus far human skull and skeletal remains have not been found. While important archeological material has been secured in all the chambers the cultural stages recorded by Harrington in Rooms 1 and 4 need only be considered for purposes of the present discussion. The interpretation of these results must await a more detailed study of the objects themselves and a more intensive investigation of the occurrence, but some of the noteworthy facts have been commented upon by Mr. Harrington [3]

In Room 1, as already mentioned, a trench through the strata revealed at the top unmistakable evidence of a Pueblo culture and of the Basket-makers. Some distance below this horizon occurred a well-defined sloth dung zone with an intercalated layer of gypsiferous material. Immediately below this dung were found fragments of charcoal, although the dung itself is undisturbed. Here also was encountered a worked stick.

In Room 4, definitely embedded in a gypsiferous layer intercalated in a zone of burnt dung and ashes, occurred a stone dart-point of an atlatl or throwing stick. Within two feet of this object and in the same layer was also found a limb bone of the ground sloth *Nothrotherium*, while in the layer of burnt dung above and not more than six feet distant from the dart-point were the charred and broken limb bones of the slender-limbed camel.

The close proximity and stratigraphic position of the artifact and the bones of extinct animals are of critical importance in determining the possible contemporaneity of man and these mammals. While the presence of a single dart-point may be accounted for on the basis of later intrusion, it is of significance to note that additional cultural material was found under similar circumstances elsewhere in the cavern. A sufficient number of artifacts has been recovered to permit Harrington to state[4] that the cultural stage includes objects of cruder type than those of the Basket-makers.

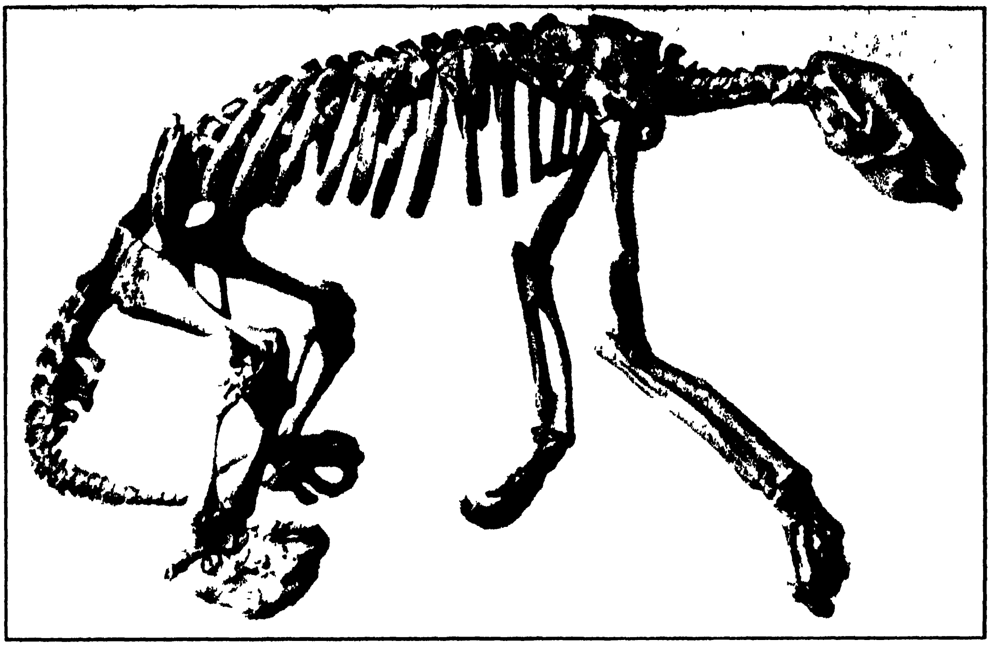
The stratigraphic relationships of the cultural material to the animal remains may indicate either a contemporaneity of man and types of mammals now extinct or a record of a past mammalian life on which has been superimposed or intruded a record of early man in America. Should the latter be accepted ultimately as the explanation of the unusual occurrence at Gypsum Cave, the period intervening certainly would appear to be of relatively short duration, measured at most in terms of a few thousands or perhaps even hundreds of years.

To the student of American Quaternary life the determination of the relative antiquity of mammalian assemblages known from within this period is of no less importance than the establishment of irrefutable evidence of an association of certain extinct types with early man. It may be readily conceded that the two questions are after all intimately related The unique facts concerning the occurrence in Gypsum Cave lend special importance to the locality in a study of this problem.

Within recent years much attention has been directed to the Quaternary land assemblages of North America and to the chronological sequence of these faunas. Noteworthy contributions to this field of inquiry have been made by that venerable student of Pleistocene life, Dr. O. P. Hay. In an attempt to

[3] M. R Harrington, *The Masterkey*, Southwest Museum, 4 (No. 2): 36–42, 1930

[4] M. R. Harrington, *Scientific American*, July, 1930, p. 36.



—Courtesy of the Peabody Museum, Yale University

FIG. 11. SKELETON OF *NOTHROTHERIUM*

SIDE VIEW, APPROXIMATELY × 1/14. REMAINS OF EPIDERMAL STRUCTURES CAN BE SEEN ON SKULL, SHOULDER BLADE, RIBS AND FEET. ADEN CRATER, NEW MEXICO

evaluate the field evidence with a view to reaching a satisfactory judgment as to the relative antiquity of a particular terrestrial assemblage of the Quaternary the student has recourse presumably to several criteria. Among others, perhaps the following may be indicated: (1) Occurrence in glacial or interglacial deposits; (2) specific relationships to existing or to other fossil or subfossil assemblages; (3) changes in distribution of types since period of deposition; (4) climatic changes as determined from (*a*) past and present distribution of organisms and from (*b*) associated plant remains; (5) type of preservation

With the exception of the stratigraphic criterion stated in (1), the criteria given above appear to have special application to the occurrence at Gypsum Cave. In some instances, however, as for example the criteria stated in (2), (3) and (4*a*), the soundness of the judgment reached as a result of their application depends in large measure upon the size and completeness of the fauna. Care certainly must be exercised in drawing conclusions where the basic facts reveal an incompletely known fossil or subfossil mammalian assemblage. With further excavations in the cavern doubtless other types will be added to the list already on record

Careful study of the plant remains preserved in the dung may offer important suggestions as to the type of flora which prevailed in the vicinity of Gypsum Cave during the period of existence of the ground sloths and associated forms. Were it determined, for example, that the plants fed upon by these creatures do not differ in type from those now found in the xerophytic flora of the region there would be no special reason for postulating climatic conditions notably different from those which

prevail there to-day. In view of the close proximity of the cavern occurrence to lake basins in southern Nevada, whose history may be related to that of Quaternary Lake Lahontan, the climatic evidence derived indirectly from the flora may be of importance in establishing the period of occupancy of the cave in relation to certain stages through which these lakes have passed in Quaternary time.

A relatively late age of the dung accumulation and of the embedded animal remains is not of necessity implied by the unusual preservation of the material. It is conceivable that under the peculiar conditions prevailing in a dry cave the epidermal structures and excrement of *Nothrotherium* may have undergone but little change, even though the period of their accumulation was long ago. On the other hand, it must be admitted that the type of preservation may with equal right be regarded as evidence indicating that the remains date from a late period of time. Moreover, had this region witnessed major fluctuations of climatic conditions since the period when the cave was occupied by the ground sloths it is difficult to believe that the remains would now exhibit the remarkable preservation which they do. If the plant remains comprising the dung are ultimately found to represent species which now form part of the living flora of the arid Southwest, this evidence and that presented by the excellent preservation of the material may indicate a remoteness of this life stage from the time of the last glaciation sufficient to place it well within the Recent division of the Quaternary.

THE WHALE SHARK OFF HAVANA HARBOR

By Dr. E. W. GUDGER
AMERICAN MUSEUM, NEW YORK CITY
and Dr. W. H. HOFFMANN
LABORATORIO FINLAY, HAVANA, CUBA

THAT *Rhineodon typus*, the whale shark, the largest of its tribe, is found in the Straits of Florida is attested by four captures on the coast of the peninsular state and by two off the harbor of Havana, Cuba. Of the Florida fish, the first (18 ft. long) came ashore three miles north of Ormond Beach on January 25, 1902. The second (38 ft. in length) was taken near Knight's Key in May, 1912. The third fish (31 ft. "over all") was captured in the Bay of Florida, June 10, 1919. The fourth (and to date the last) specimen from Florida waters was secured at Marathon, 16 miles below Long Key, on June 9, 1923. The three captures near Havana will now be described in some detail.

The first of these, the fifth record for the Straits of Florida, was made on November 20, 1927, at Jaimanitas, a fishing village about five miles west of the mouth of Havana harbor. This fish and its occurrence in this region we have recorded elsewhere.[1] It was an adult male 32 feet in total length, its greatest girth was 18 feet and its estimated weight was nine tons. The weight of the liver was said to be 900 pounds, and of the heart 43 pounds The body of the fish was reported to be six feet deep, and the small of the tail at the base of the caudal fin was so large that a tall man could scarcely encircle it with both arms. An idea may be gotten of the

[1] *American Museum Novitates*, no. 318, 7 p., 4 figs, 1928.

FIG. 1. THE FIRST HAVANA WHALE SHARK

PARTLY OUT OF WATER AT JAIMANITAS AS SEEN IN LEFT-FRONTAL VIEW. NOTE THE HARPOON IN THE LEFT GILL REGION. NINE MEN ARE PERCHED ON ITS BACK.

FIG. 2. RIGHT LATERAL VIEW OF THE FIRST HAVANA *RHINEODON*
SHOWING THE BLUNT HEAD, MEDIAN FINS, LATERAL KEELS AND THE UPPER LOBE OF THE TAIL FIN.

immense size of the fish by reference to Fig. 1, a front-lateral view showing the huge fish with nine men on its broad back.

An even better idea of the size of this great shark may be had from inspection of Fig. 2 in which the fish is shown in lateral view. Here may be seen the longitudinal keels or ridges running from the head region backward along the side. Crossing these at regular intervals are vertical white or yellow bars. The intersection of keels and bars gives a checkerboard-like appearance to the sides of the fish. This is accentuated by the large white or yellow spots set in the middle of each square. This is plainly seen in Fig. 5 showing in detail a part of the side of the fourth Florida specimen. The local Cuban name of the fish is *pez dama,* in allusion to this. Now *pez* means fish and *dama* lady, but the

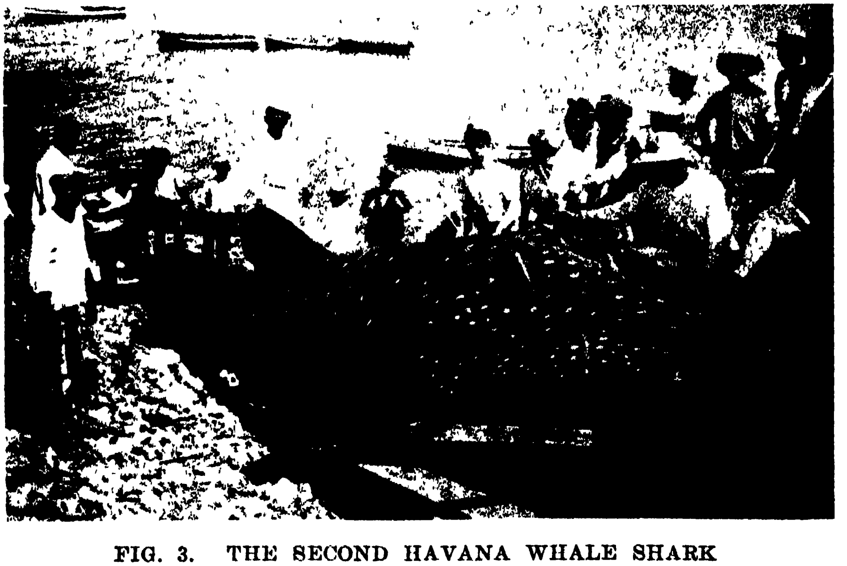


FIG. 3. THE SECOND HAVANA WHALE SHARK
ON THE SHORE AT COJIMAR. NOTE THE WOODEN FRAMEWORK ON WHICH IT IS LYING, THE HARPOONS IN THE HEAD REGION AND THE THIN STEEL ROPE CONFINING THE RIGHT PECTORAL. THE WEDGE-SHAPED DARK REGION ON THE HEAD IS A SHADOW CAST BY ONE OF THE ONLOOKERS.

Cubans do not mean "lady fish" by this appellation, for *dama* also means checkerboard. Hence when it is locally called *pez dama,* this means "checkerboard fish" to the hearers. The blocked-off sections of skin with their enclosed large round spots certainly do resemble a checkerboard with the checkers in the center of each square.

In a head-on view of the first fish, Fig. 4, one may get a clear idea of the cavernous mouth, large enough to take in a grown man. Now the term shark is synonymous with voracity and ferocity, and the mouth (especially of a large specimen) is supposed to be full of large sharp cutting teeth. In the lower jaw of this 32-foot specimen the tooth band is fairly visible. The closely set backwardly pointing teeth are only about one eighth of an inch in length, and, unlike the dental apparatus of most sharks, can function for retention only.

As for ferocity, the whale shark is everywhere reported as sluggish and stupid—this has been markedly true of all the Florida specimens. This Havana shark allowed a boat to be "nosed" against him while a harpoon was being thrown into his left gill region. Even after being harpooned, he made little or no disturbance but merely dragged the boat around after him for some 20 hours until finally, weakened by loss of blood, he allowed himself to be towed to the shore.

The second Havana whale shark was captured on March 10, 1930, off Cojimar, a seaside town about five miles east of the mouth of Havana harbor. We have made a faunal record of it elsewhere.[2] This fish like the other was also a male and but slightly larger (about 34 feet over all) than the first. It or another fish had been seen off Cojimar for some three years previous, and had been appropriately dubbed "El Elefante." So well known was it that a merchant of Havana had subsidized a crew of fishermen to hunt for it, and had provided them with specially made tackle—harpoons, ropes and buoys.

The manner of capture of the Cojimar

FIG. 4. NEARLY HEAD ON VIEW OF THE FIRST HAVANA *RHINEODON*
SHOWING THE CAVERNOUS MOUTH WITH THE TOOTH BAND OF MINUTE TEETH IN THE LOWER JAW. THE HARPOON SHOWN IS THE ONE USED IN ITS CAPTURE

[2] *Science,* 71: 639-640, 1930.

fish was different from all other methods known to us for the taking of the whale shark. The fishermen in two gasoline launches easily approached the sluggish fish, and, manipulating a thin steel cable by means of long bamboo poles, managed to put over the head and around the body of the fish a double slip noose. The small wire rope was then drawn tight about the body of the fish, confining the pectoral fins and materially hampering the activity of the fish. This shark was captured in the open sea about a mile from shore where the water was deep enough to enable the fish to escape by diving. To hinder his submerging and to locate him if he did dive, two steel petroleum drums were affixed to the steel rope. Thus held more or less at the surface, *Rhineodon* was attacked with harpoons and also about 50 shots were fired into him from a Winchester rifle.

Thus held both by the lasso around the pectorals and attached to the drums, and by harpoon lines fastened to the boats, *Rhineodon* was towed and driven into Cojimar Bay. The fish does not seem to have offered any material resistance to all this, and finally died from loss of blood about 24 hours after he was attacked. But although at the shore, it was tremendously difficult to get the fish out on the beach. Forty men tailing on ropes were unable to drag him out, and this was finally effected only by getting him on a raft-like structure and hauling this and the fish ashore by means of a winch or crane.

FIG. 5. A PORTION OF THE SIDE OF THE WHALE SHARK

SHOWING THE CHECKERBOARD ARRANGEMENT OF KEELS, CROSSBARS AND SPOTS WHICH LEADS THE CUBANS TO CALL IT "PEZ DAMA"—CHECKERBOARD FISH.

Fig. 3 shows the second Havana whale shark on its wooden skids or framework drawn out on the beach. Plain to be seen are the encircling wire rope and the two harpoons in the region back of the head. The color markings show plainly save that over the head is a wedge-shaped black shadow which gives the head a bizarre appearance. The very small right eye is seen low down on the side of the head, just in front of the piece of wood on which the body lies. Unfortunately we have not been able to get any other photographs of this specimen.

From the data presented above, it seems very probable that other whale sharks will be taken in the Straits of Florida and in adjacent waters. Rumors reach us of various great sharks seen in Florida waters, some of which may possibly have been whale sharks. An unconfirmed newspaper account tells of one seen this spring off Bimini, Bahamas. And for waters off Havana harbor, the fishermen speak of various great sharks, some spotted, seen at various times of the year. We know practically nothing of the habits of *Rhineodon,* but it seems to come near the shore and hence into shallow water at those times of the year when the sardines are shoaling. This agrees with accounts coming from a scientific correspondent in the Seychelles Islands, western Indian Ocean. There seems to be no doubt that it feeds on these small fish.

REFLECTIONS ON THE STRUGGLE FOR EXISTENCE

By Dr. GEORGE J. PEIRCE

PROFESSOR OF BOTANY AND PLANT PHYSIOLOGY, STANFORD UNIVERSITY

If any excuse is needed to justify resurrecting this hackneyed phrase it can be found in the fact that the phrase is by no means as meaningless in reality as it is in the minds and mouths of most. To those who lead the sheltered and secure if modest lives of Academe there may come affliction, trial, bereavement, hard work, enforced economy, monotony and protractedness of dress, and the various other ills of which they grumble; but their next meal depends upon their own immediate exertions only as they may voluntarily and for pleasure be carrying lunch or whipping a trout stream. This next meal is not the fruit of the earnings of the next odd job; and the night's rest comes elsewhere than on a park bench, in a "flop house" or in an ash barrel. They are a protected people. Connected with educational establishments the parts or the whole of which may find the annual statement "in the red," they find it so because authority permits living beyond the corporate income, knowing the need, the opportunity, the obligation, and confident of not too long deferred recognition and readjustment. They do not go to the bank to find that their salary check has not been deposited on the date due. Like other salaried persons who are parts of honorable and successful organizations, they can count on the monthly, quarterly, annual income. This is very different from the independent in business, financed as an individual and not indebted to stockholders common or preferred. The independent in business, balancing his books at the end of a stormy period, may find that for himself, when all current debts are paid, there is nothing left to compensate him for his year's labor, thought, anxiety, nothing to support himself and his family. From this professors are a protected people. There are no uncertainties of trade with them, once they have made the general bargain as to rank in salary; though, in the academic world, as elsewhere, energy, worldly wisdom, executive ability and persistence yield their expected returns.

Professors are even more protected than this, for they know that unless they are worse than flagrantly idle, unless they are flagrantly vicious according to the usual standards, they will almost certainly be continued in their secure if modest incomes. They are not obliged to maintain a quota of sales, or to do any other stipulated task, lest they lose the agency for Fords or forestry or forensics, in their district. There is no struggle for existence: they survive anyway, except in those rare instances which are investigated by the committee on academic freedom of the professors' union. The reason and the results of this protection may retain our interest for a moment.

In academic life there is no single gauge by which to measure usefulness or attainment, for there are so many kinds of work to be done. The teaching of undergraduates may be done with such high and single purpose, and such charm and dignity, that the bachelor of arts carries through life affectionate respect for the professor who showed him all these, with his Greek; or it may be so done that most bachelors remember only the amusing vagaries of a teacher, the contagion of whose enthusiasm may be caught by but few, but which inspires and guides graduate students to seek

to penetrate the depths. The conduct of academic business by a distinguished teacher may be such as to clog the works, while a generally unknown man may act with such tact and promptness that one is unaware that every one is comfortable, that the library has the books one needs (where did they come from? who ordered them?), that equipment and material are ready when required. This is good housekeeping. The coordination and cooperation of undergraduates, graduates, departments, staff, alumni and the general public are not the product of chance. Some one man in the university brings it about, continuing and increasing it. But such sympathetic appreciative understanding does not come about as the result of ways unchanged since the Universities of Alexandria and Bologna were founded by a process of aggregation. The colleges and universities do not meet the changing needs of a changing world except as interest and thought are applied to the new problems with no less earnestness than to archeology and paleontology.

So, with no such single simple gauge of individual and corporate usefulness and attainment as the sales quota or the cash dividend, the universities find themselves protecting dead wood from the results of decay at the same time that they are fostering and promoting the most precious products of civilization, its scholarship and its youth, increasing their usefulness and their satisfactions. A university is a grotesquely inefficient organization, but a vastly effective one. It is the former because the phenomenon so general in the world of nature, the struggle for existence, is excluded from it; and it is the latter for the same reason. I have in mind an average professorial garden, one in which the work is done by loving and not hired labor, in which there may be weeds, but in which also there are unusual things, plants or arrangements. The yields a commercial florist might find quite inadequate; but pleasure, interest, health and even some biological knowledge (such as acquaintance with snails) are regularly produced. In that garden there is and there isn't a struggle for existence; for the gardener removes what he will, the survivors are not the survivors in any ordinary struggle for existence, they survive according to the intervention of the god (or the goddess) of their little world. Our universities are like our gardens, planned for a little more than the available income, not standardized like pianos, but each possessing its own quality like an organ. And in our universities, as in our gardens, plants which are not doing their utmost may nevertheless justify their retention. Productive scholarship, zealous research, efficiency, leadership and all the other rubber stamps of our vocabulary yield on reflection to charm, character and clear thinking—the gifts of God and the product of man, the examples more potent than precepts in academic as well as in so-called practical life.

Brought up where the New England conscience originated, I have often wondered, since coming West, why work should be considered so virtuous. One must work to keep alive where weather, soil or subsistence are inadequate. Does not the New Englander therefore make a virtue out of a necessity? And is not this perhaps the origin of all virtue, morals and religion? Why does not the world owe us a living? Do not those organisms, human and other, succeed best which are not independent, self-supporting, self-nourishing?

While granting that analogy is not argument, as a biologist I automatically turn to the world of nature for answer to some of my human problems. If I correctly apprehend the plant and animal world, I see one peopled with unnumbered kinds of living beings.

They range in size from the invisible to the monstrous; in behavior from the motionless of the sea-anemone and the oak to the swiftness of horse and swallow; from complete, independent, individual, self-contained existence to the parasitism of the invisible inhabitants of the body cavities of their hosts. They vary from the persistent shyness of the rabbit and the snail to the boldness of the blue jay and the squirrel. I see all sorts of associations, all sorts of competitions, all sorts of selfishness, and no manners The chipmunk, favorite of children and of many physical adults, becomes a secondary tenant of my Sierra camp when melon seeds and other delicacies useless to man are available When Mr. or Mrs. Chipmunk comes alone, or brings the children, they present a charming, not to say edifying, spectacle; but let Mr and Mrs. come together, the children will wisely stay at home (whether of their initiative or their parents' I do not know), and there is no evidence of gallantry or of wifely devotion, there is no conjugal felicity, there is no partnership, no sharing in prosperity, there is only the struggle for melon seeds, often accompanied by a cuff or a snip and a squeak, and that too in spite of the fact that Mrs. Chipmunk may be carrying Mr. Chipmunk's unborn children, and necessarily be less swift and graceful than in her younger days. Perhaps Mr. Chipmunk reforms and takes on some manners when Mrs Chipmunk is confined, but he (and she) certainly have none before and after that event.

And what of the children? Begotten, *nolens volens*, they come into the world together, without choice of parentage, degree of prosperity or social status. Fed they are for a time, and warmed also. The world owes and provides them a living, but it doesn't last long; and even amongst themselves the little ones struggle, for more milk, more warmth, more comfort and protection. Shortly they are themselves scurrying for melon seeds and running away with them, with a cuff or a snip and a squeak for their fellow strugglers against death by starvation.

In the behavior of my chipmunk neighbors I see no sentiment, no altruism, no code of morals or ethics, no parental care beyond the brief period of helplessness, no filial devotion, no care for the old and feeble There are no feeble chipmunks, and I have never recognized an old one.

Furthermore, the chipmunks are completely democratic. Human democracy has been variously defined as a state offering equal opportunity to all, or, as I heard a scoffer say once to the major "minor prophet of democracy," a condition of equality among autocrats Human democracy was invented by the brighter sufferers in order to equalize the struggle for existence among nationals of the same state or country. It was a step away from individualism, and yet the individual has flourished under it as never before. The complete and perfect democracy of the individual, as one sees it among chipmunks and many other animals, is not the aim of political or social leaders among men. These are in fact promoting class or social democracy instead, equalizing opportunity by reducing social or political or economic differences. And certainly the aim is not equality but advantage, the benefiting of the promotor and his or her following. The socialist wishes socialism and the social revolution only so long as his own self, family or class will be benefited thereby. Does one encounter a rich socialist, yet a sane one, who advocates the destruction of the system of property? I have yet to see one, although I have met several persons who still consider themselves radicals, socialists, progressives or what not but who, when given the opportunity, so con-

ducted themselves that they were mistaken for conservatives, reactionaries, stand-patters.

In a perfect personal democracy, where all are created free and equal, and are entitled to life, liberty and the pursuit of happiness, there must be inequality if the members of the democracy are to thrive, for a democracy without leaders is merely a free for all, a struggle, without perspective, for existence. In the chipmunk world, so far as I know, there is equality of a sort, for the chances of getting melon seeds or grains from the wild grasses are the same for all chipmunks in the same vicinity; and there is inequality, for the swiftest, most agile, most intent and most inconsiderate will get the most seeds or grains. Such an individual will have the best chance to survive the winter, for he will be better fed, better fatted and better furred than his fellows; and he may have a "bigger and better" family in the following spring Because of their individualism, however– or as New England used to have it, "Every man for himself, and the Devil take the hindmost"– –this bigger and better family does not constitute itself a leader in chipmunkdom, the democracy remains a pure democracy, with equal opportunity to all, equal necessity to sink or swim, live or die, survive or perish.

In the competition with the other animals seeking melon seeds, grains or nuts one sees an Ishmaelitish struggle, each against every other and every other against him. There is never more than momentary protection for any one, never more than momentary advantage of any sort. Greater weight, strength, agility and determination may characterize one of two animals fighting for "a place in the sun"; and if the fight be like those chemical reactions which run to the end, there will be only one survivor. The same advantages may be possessed by individual chipmunks over other individual rodent competitors, with the same result. Such competitions may result in individual initiative, originality, astuteness and downright intellect of most astounding sort. If I could tell wild animal stories as I have heard them from the lips of the bronzed, brave and unsentimental members of the United States Biological Survey, you would marvel with me at the skill enabling a killer wolf, for example, to maintain himself or herself on the range for months in spite of bounties, traps, guns and mounted men. Survival is the fruit of sheer intellectual ability and attainment, of competition whose only limit is the capacity of the contestants, whose end is the limit of endurance of one or both parties, and in which both brain and brawn are needed and used.

In favor of the killer wolf a considerable amount of sentiment might be aroused in this community, though not in Utah, because the wolf after all was already established in the land, with his own high standard of living, his considerable degree of comfort, not to say elegance, his intellectual quality as witnessed by his small family and important social connections. What justification is there for white men attempting to penetrate a territory in which Indians, wolves, chipmunks and grasshoppers had attained such a balance of power as to constitute a fairly commodious system? Did necessity or the desire for otherwise unattainable advantage drive the Pilgrims to the bleak coast of New England? Did necessity or desire for advantage compel the westward movement? Was the desire to abolish slavery, or the desire to equalize labor and other costs of production, the fundamental cause of the struggle which did not equalize wages in the North and the South, but which has made of our country the most powerful

economic unit to-day? Is it fear of economic competition or of undue crowding in our empty spaces which is the inspiration of our objection to Asiatic immigration?

In the modern human struggle for existence, for comfort, for prosperity and for peace of mind we have gone very far from the simple individual democracy which is a free for all in a sparsely settled area. Organization and leadership have destroyed the individualistic condition, and we have attained a greater degree of prosperity for many, and indeed greater comfort and safety for all, than would otherwise have been possible Combination among equals may lead to more successful dealing with competitors of other sorts, but it promptly leads also to competition within the combination, and out of this internal competition come leadership and subordination, cooperation, discipline and obedience. Equality prevents success in the struggle for existence and destroys itself sooner or later.

Why there must be the struggle for existence is obvious enough, for one need realize only that the world is too full of things, living and lifeless, for the individual to survive without effort Out of the struggle for existence have come combinations among animals which have placed some far up in the scale of existence, while those which have persisted in pure democracy, in individual equality, have developed but little more than the plants. One may point with pride to the forest as an example of a successful pure democracy; but so are a poison oak tangle and a colony of gelatinous algae successful in a way, but only in a very limited way.

Among ideals there is a corresponding struggle for existence. We have seen that under the conditions prevailing on the earth to-day pure democracy is impracticable. We have abandoned it in fact, though not in fancy, for we have accepted the ideas of combination and leadership. To these ideas of combination and leadership we have attached altruistic ideals in order to control combination and leadership within such bounds that, while national or local human society is successful in competition with its neighbors, the components of the society may have a fair share in the benefits. We want and submit to leadership so long as we consider it good for ourselves. We choose leaders, or have them chosen for us, according as we vote for president or install a college president. And according to our tastes, what we enjoy, the principles we were provided with and perhaps still retain, we are citizens of the republic, not calling our duty done when we grumblingly pay taxes and criticize the administration, municipal, state and national; or we are wards of the commonwealth as truly as if we were Indians or incompetents.

In so-called practical life there have developed media of exchange—money, position, invitations and visiting cards. In academic life we have a little of these, and some others. Perhaps the most acclaimed of these others are deanships and research Deanships are like certain plants, thriving and prolific only under quite suitable conditions.

The history of the American universities records great growth in attendance, the development of organizations designed to give to their students the utmost advantage of residence, but with an increase in income not equal to the costs of increased numbers and the increased living expenses of their staffs. American youth has resorted in great numbers to the universities and colleges in the belief that in them it would find advantage, temporary or enduring, proportioned to the expenditure of time and money. Without our specifying whether this advantage is social, scholarly, vocational or amusing, it is gen-

erally accepted as adequate. The numbers have come, and the necessity of caring for them has resulted in organization which has produced advancements more rapid than scholarship alone could win. These promotions in rank and salary have been awarded in recognition of the need of the hour and of the executive capacity of the individual. The phenomenon has been so general in America that the young scholar would have been blind or hopelessly stupid not to recognize that the surest road to academic preferment and economic amelioration lay in this direction rather than in research. Pure research as a means of livelihood was not safe

We are engaged in our respective subjects of study and teaching because they are what interest us most; we are more curious about them than about any other subjects of human inquiry; but we have, in addition, interests and obligations which, if we are conscious and conscientious, we also feel that we must attend to The man who marries and has children has duties commensurate with his growing privileges. The man married or unmarried who lives in a commonwealth, as distinct from a benevolent academic autocracy, has obligations as a citizen These are not limited to the periodic casting of a dissatisfied ballot for candidates for public office too often only a little less inadequate than their rivals. The man, therefore, who is primarily interested in philosophy, philology or finance finds himself a citizen, a husband and father, a bread-winner. Unaccustomed in this new country to the old world conventions and conveniences of marrying wealth and employing servants to care for household and laboratory drudgery, the young man who contemplates a life devoted to research realizes that it is attainable only at great sacrifice, not necessarily exclusively his own. Even if he have an adequate income by gift, bequest or marriage, the academic establishment of which he is a part is unlikely also to have an income adequate to the provision of such persons as will so relieve him of drudgery that he will be free to pursue his own taste without thought of others. Conditions generally in this country, then, are economically, socially and conscientiously against the scholar who would prefer research to the writing of income-producing books, to the rendering of extra-academic professional services for pay or even to the filling of intramural academic office.

The young scholar may even ponder the question whether the curiosity which he feels about nature or society or human history is in itself of finer quality and more deserving of support by his fellow citizens than other men's hobbies, for which they themselves pay "The honor and danger of the trusts to which we are called"—to quote the prayer which is heard on academic occasions in one of the universities of the Far West—imply an obligation so impressive that one may modestly wonder whether one is fulfilling it in self-indulgence. Collecting Indian skulls may be no more honorable than collecting Indian baskets. Collecting "data" may be no more valuable than collecting postage stamps. From stamps, data, baskets and skulls one may derive personal satisfaction; one may learn the ways of human and of other nature, one may discover laws of development, distribution and design, but one will stop at one point or another, short of the highest goal, according to the limits of imagination, ambition and conscience.

Research, then, is not in itself more than the vision of those who pursue it. It is worthy or unworthy according to the ratio of the cost to the value of the product. It is like all other human things, fine or selfish, a carving or just chips. And yet, because we have so

often heard research extolled as the scholar's highest aim and highest service, conscience pricks us if we do not make some other scholarly effort than the mastery of some field of knowledge and the training in it of those who resort to us for guidance. I assume that there is not one of us who is not curious about this or that "unknown," who is not desirous of satisfying that curiosity, who would not gladly devote himself to the satisfaction of such curiosity, who would not make his contribution to knowledge if his obligations permitted. To see one's duty fairly, in its true proportions, in its true relations to the university of which we are parts as well as employees, and to those about us; and then to do one's duty, that is what each one desires, and for the most part what each one does Research is but one duty, one ideal. Devotion to it may be as misguided as entering a cloister. To be a saint or a scholar may be very useless!

As we pass in this western world from the pioneer stages, in which the white man has successfully displaced in the struggle for existence the former occupants of the territory which he has invaded, we approach the conditions prevailing in the older countries of our world. In the oldest countries, in the crowded conditions of Asia, in the less old and less crowded conditions in Europe, we see what is before us, unless man learns to effect a new balance in the civilization which he is making. In the civilizations of which ours to-day is the modern replica, essentially the same balance has always prevailed Honors, rewards and power have been given always to the non-producer, first to the man of might, the militarist, later and to-day to the man of means, the plutocrat. We have always attempted to do what is contrary to nature. We light the dark hours, we build against gravity; man, a land animal, travels upon and in the sea; and now he attempts to traverse the air. He scorns time and distance as facts, and reduces them to their lowest terms. He ignores his absolute dependence upon food and drink, and crowds together so that neither he nor his neighbors can grow or capture food. By the bounty of nature he survives—destroying the producers of food. He fells the forest for fuel, housing, furniture; he converts the grazing spaces to golf courses or other less amusing uses; he makes the land so valuable that it can not be planted to food crops; he goes where rain is scanty, and he makes the soil naked so that it washes away. He demands food and drink and, with niggardly hand and unthinking mind, plans what he is pleased to call "farm relief." So far as I can see, the world will never be safe, for democracy or anything else, until man recognizes his absolute dependence, not upon raw materials, mineral resources, coal, oil or other sources of usable energy, but upon the two things which he can not make, and one of which it would seem that he never can make in sufficient amount to satisfy even his minimum requirements. The clothes moth makes its own water by its own physiological processes; but who would pattern after the clothes moth even if he could? But no animal makes its own food In this land of white collars we reward those who can buy them. We do nothing for the men who grow the linen, the cotton and the starch to make them serviceable and, according to our esthetic standards, fitting We compensate, more or less uncertainly, the man who grows luxuries on land for which he paid $1,000 an acre. We force the wheat farmer to produce bread at such a price that he must grow it so far from the market that his own wage, being what is left after paying for freight, handling, storage and the percentages of every handler between himself and the con-

sumer, is so small that a grain-broker would consider it negligible. Our food must be grown on the cheapest land if we are to buy it in sufficient quantities. The cheapest land is that most remote and hence least desired for other uses. This fact entails the long and costly haul to market, the repeated handlings by man or machinery, the risks and rents in transit and storage. The milling would cost roughly the same anywhere and at any time. The agricultural problem and this is the crux of the problem of the struggle for existence - -is due to our having emphasized and rewarded everything but the essentials of our existence.

In this funny world of ours, in this amusing country of ours, we have long discussed the device of tariffs. We have invented octroi, customs dues and finally duties for the protection of infant industries. We have succeeded so remarkably that Fords and safety razors are in the hands of almost all of us. But breakfast should follow the use of the razor, and lunch and dinner must be supplied to the driver of the Ford. Bread, meat and milk are furnished in return for wages the very lowest. This has always been the case, but it is necessarily so only because of our misconceived civilization, a civilization the honors and rewards of which are given to the least necessary parts, a broadening civilization the pyramid of which we have built upside down. The reason for the turning of youth from the farm to the town is the miserable, the delayed, the uncertain pay for producing what we can not get along without. And if, in the struggle for existence, the farmers fail, our civilization will have destroyed itself. We grant, in debate, that agriculture is the foundation of prosperity and even of existence, but we do nothing to preserve it, we do everything we can to undermine it. We charge our colleges of agriculture with failure to produce farmers. Have our medical schools failed to produce physicians and surgeons, our law schools failed to produce attorneys? We reward their products with the pay they require. Our theological schools have failed. Why? For the same reason that our colleges of agriculture have failed, namely, that the compensation for training and knowledge in these two fields is so inadequate. We still see some young men of brains and character, as well as devotion, entering upon the ministry to souls; and perhaps some young men of brains and character and devotion entering, with inherited capital, upon the ministry to stomachs. But without capital how can one start to produce wheat or corn or meat? If the capital be only the land, and the young man be unwilling to use wife and children as laborers, how far can he go? He must buy seed, implements and transport for his harvest, and his pay is what?

I see no immediate prospect of our civilization remaking itself. On the contrary, until civilization is forced by hunger, in the struggle for existence, to insure its food supply, the care of individual and public health, the protection of property and even the aspirations to a higher life will simply intensify the struggle for existence We must readjust our rewards; we must compensate the producers of necessities at least as richly as we reward equal ability in other lines.

But to do this implies a social revolution in comparison with which those of the recent and more remote pasts are trifling; in which human nature, always controlled more by sentiment than by reason, will have to overcome the habits of centuries; in which wars, epidemics, famines will have their terrible parts; and before man achieves it or understands it, will have taken enormous toll

in human life. For until we have secured our food supply, we shall continue to be in jeopardy.

On the Mojave Desert is a settlement of six hundred souls, watered by a slender pipe-line miles long, supplemented by wells which furnish water so alkaline that it can be used only for washing and which gives the skin a curious sliminess. All the food of the community comes over a single track railroad thirty miles long. The community can make no water, grow and capture no food, on the desert. Nor would the community be better off if it consisted of one person instead of six hundred, including women and children, for the Mojave will not feed even a "desert rat" New York City has enough milk for a day and a half, other food for three days. Other communities are no better off, and if we all became farmers when our supplies fail it would do no good, for it takes time for food to be produced. Food is seasonal; it must be grown in summer and stored against the winter, spring and summer, till the succeeding harvest refills the granaries, or it must be captured. Races dependent upon the chase, whether upon land or sea, are limited in numbers and live scattered over extended areas. But civilized man lives no less uncertainly, though less obviously in jeopardy, till war or pestilence or calamitous weather reveals his weakness. Perhaps you imagine I am indulging in diluted allusions to the doctrine of Malthus. Not so. What I have in mind goes much further than Malthus; is truly wild if you will. While I believe what I think Malthus said about the relation of subsistence and population, I am saying that to insure any population beyond the sparsest and most active in the chase there must be due reward for the production of subsistence. The hunger of others will not cause you and me or any one else to take the bread from the mouths of our wives and children or to rob them of their seed corn for the next year's harvest. We saw this very recently in Russia. The farmer will continue to support the town only if he is paid for it, not if he is forced to the wall in the struggle for existence. His work, the most necessary and hence the most important, deserves no less reward than that of others. If he had learned the arts of combination we should know ourselves to be at his mercy. He seems to be at our mercy, for we force him to sell, and to undersell his neighbor. The result is the diminishing farm population. If this go too far, we shall all be hungry.

But if, instead of basing our civilization on an insecure food supply and pleasing ourselves with luxuries, we insure the production of food by proper compensation for the producer, we can be sure of the future. Then man, who has overcome the insufficient buoyancy of the air, the insufficient aeration of the sea, and the limitations of time and space, may look forward to a truly glorious development as the safest as well as the highest land animal.

QUANTITATIVE DIETS VERSUS GUESSWORK IN THE TREATMENT OF OBESITY AND DIABETES

By Dr. H. GRAY and JEAN M. STEWART

FROM THE DIET LABORATORY OF THE MEDICAL DEPARTMENT OF THE STANFORD UNIVERSITY HOSPITAL

"The true remedy for diabetes is found not in the pharmacy but in the kitchen."—*Cantani.*

DIET to-day is a matter over which a surprisingly large group of people exhibit serious concern In some instances it is laughable; in many tragic. In all it is a nuisance to the central figure, the family and only too often the circle of friends. Commonly dieting is conspicuous for its faddishness and remissions as soon as a few pounds have been lost: misguided and wasted effort which place that diet in the category of patent medicines. On the other hand, education in measured diets has become the cornerstone in the treatment of an increasing number of disorders of the chemistry of the body, such as obesity, diabetes, nephritis and epilepsy. This is due to the rapid expansion of knowledge about the basic *values* of the familiar *articles* of food. In this teaching and demonstration of foods an ever-growing rôle is being played by the dietitian.

QUALITATIVE DIETS

By omitting certain articles of food, such as coffee when nervous, tobacco when short of breath, sugar and bread when diabetic, many patients obtain relief so substantial that further details are unnecessary; they are fortunate. Yes, fortunate, for after all there are few of us who escape some restrictions on our liberties!

QUANTITATIVE ESTIMATED DIETS

The distinction between qualitative and quantitative diets has not been made at all clear to patients, and is of the first importance to all those who fail to improve on qualitative régimes within a reasonable length of time, say two to four weeks at the outside. The cause of failure as a rule is that while the patient is restricting certain articles of food she unconsciously increases others. To overcome this tendency she must be taught the underlying principles of the quantitative diet, namely, that any article of food may be eaten if in small enough amount, whereas no food should be eaten in unlimited quantities; that food must be thought of in terms of calories, carbohydrate, protein and fat, and that the quantitative estimation of these values is imperative. This quantitation may be begun in simple household terms of ounces and tablespoonfuls, one ounce being equal to one heaping or two level tablespoonfuls.

The teaching of these principles is started in most good clinics by requesting the patient to write down everything she eats for the next three meals, with a statement of the amounts as nearly as she can judge in tablespoonfuls or ounces, and to return with the list.

This is the sort of list she is apt to bring in:

Breakfast.
½ grapefruit, cereal 4 tablespoonfuls, toast 2 pieces, butter, coffee, cream.

Lunch.
1 chop, baked potato 3 heaping tablespoonfuls, carrots 3 heaping tablespoonfuls, sliced peaches and cream, graham bread 1 slice, butter, tea.

Dinner.
Slice roast beef medium sized, mashed potato 3 heaping tablespoonfuls, vegetable salad small, apple pie, bread 1 slice, butter, tea.

In any first lesson suggestions will be

necessary, and in the above case the patient's attention is drawn to the statement about the meat, pointing out that "one chop" may have consisted of one, two, four or more ounces, and that with articles like this the patient who has seen the chop can make a better guess than we can, so what would she hazard? Then we write it in. Similarly with the roast beef, with the salad, the butter and especially the pie. We point out the difficulty for us to do the estimating of the actual amount. On reaching the foot of the list we return it as a model, and ask her to repeat the process for two days and to return.

At this second visit she brings the two days' lists, and we calculate the food values rapidly for our own guidance. If the totals differ too widely we surmise in spite of the labor that went into them (and it is considerable for the patient on these first attempts), that the lists do not tell the patient's habits. More lists are asked for until a fair degree of uniformity becomes apparent.

A sample of a satisfactory calculation after the third visit may now be shown in Table I, with the explanation that just as tablespoonfuls were converted into ounces, so ounces are now converted into grams, because computations are easier in the metric system. Each ounce is considered equal to 30 grams, which is not exact but is near enough for the purpose of practice; thus three ounces of meat will be seen here as 90 grams, ten ounces of 5 per cent. vegetable as 300 grams, and so on. To compute the diet it is necessary to know the amount of the carbohydrate, protein and fat in each article of food; these values are to be found in the monograph by Atwater and Bryant, "The Chemical Composition of American Food Materials," Bulletin 28, Revised Edition, which was first issued in 1906; it can be purchased by sending ten cents in coin to the Superintendent of Documents, Washington, D. C. We have here used the simplified values given by Joslin in his peerless "Diabetic Manual," published by Lea and Febiger, Philadelphia, edition 4, 1929.

Now we have a more definite basis to build on, both as regards the articles of food this patient likes and the amounts of them which she is accustomed to eat. Recommendations are made appropriate to her condition, to increase such and

TABLE I

AVERAGE NORMAL DIET FOR A PERSON WEIGHING 61 KILOGRAMS (134 POUNDS). THE ESSENTIALS ARE THE AMOUNTS OF CARBOHYDRATE, PROTEIN, FAT AND CALORIES WHICH MAY BE DERIVED FROM AN ENDLESS VARIETY OF ARTICLES OF FOOD

Article of food	Breakfast	Lunch	Supper	Total for the day	Carbohydrate	Protein	Fat
Meat cooked		90		90		24	15
Egg		1		1		6	6
5 per cent. vegetables		300	300	600	20	10	
Oatmeal (dry weight) .	30			30	20	5	2
Bread	30	15	30	75	45	8	
Butter	10	10	10	30			25
Milk	240			240	12	8	8
Grapefruit	100			100	5		
Orange		150	100	250	25		
Olive oil			20	20			20
		Total grams			127	61	76
					×4	4	9
		Total calories			508	244	684 = 1427

such, to decrease such and such, in about this and that quantities; and after three days to bring her lists again. If this treatment shows results, again we call the patient lucky. If not, we must help her over the next necessary hurdle, namely, use of a food scales.

Quantitative-weighed Diets

At this fence many patients shy; they will try any odd diet they hear of, particularly if it has a catchy or imposing name, or if it consists of only two articles or is otherwise so simple that it is easy to learn from, and to tell to, their friends. They do not realize or are reluctant to admit that such diets are one-sided and therefore can not be expected to be adequate for the needs of the body for more than a very short period; they resent being reminded that successful dietary treatment seldom can be achieved by a month's enthusiasm followed by a return to previous habits, but that success depends on developing new habits suitable to their personal needs.

When, however, they are persuaded to give a fair trial to weighing what they eat on a Chatillon or Hanson movable dial food-scales, or even a postal scales, and calculating the values until they have learned the real instead of the apparent weights of the various articles, they will as a rule be astounded to learn these straightforward facts:

1. That weighing is not so much work as they anticipate.

2. That after a week or two of such weighing, supplemented occasionally later by a day or two of repetition, they generally will be able to return to estimation by the eye.

3. That the same volumes of various articles of food differ greatly in weight.

4. That the same weights of various articles differ even more surprisingly in values of C, P, F.

5. That after the practice with figures in weighing, calculation of the values becomes easier.

6. That after having learned some calculations, they will be able to make substitutions in the diet ordered in such a way as to keep the values satisfactory to the physician and at the same time to keep the menu palatable to themselves.

The requirements of all diets have certain points in common: (1) Sufficient calories, (2) adequate protein, (3) carbohydrate and (4) fat in reasonable proportions, (5) vitamins A, B, C, D, E and G, (6) minerals and (7) bulk.

Obesity

Excess fat is not only closely associated with the onset of diabetes in at least three quarters of the cases, but in other respects is a menace to long life. Overweights in general have a mortality more than twice the normal, but extreme overweights have a mortality about thirteen times the rate for underweights, as recently demonstrated by Dublin. The most favorable weight is that for one's height at the age of thirty years, as shown by the Association of Life Insurance Directors and Actuarial Society in 1912, from whose table is drawn the abridged form shown in Table II.

In order to reduce weight the principle concerned is the reduction of the total number of calories. The bulk of the articles of food, it must be remembered, does not tell the fuel value; to know this we must figure out the calories. At the outset, therefore, we list the articles eaten and make the computations described above under normal diets. When we have ascertained the patient's dietary habits, we then: (1) reduce the number of calories, and (2) plan that the patient shall take the amount of protein necessary for health. As to the carbohydrate and fat distribution there are many theories. These can not be detailed here; it is enough to state that they are quite secondary. For individual patients various distributions may be suitable because of special circumstances in the judgment of the physician or

TABLE II

AVERAGE WEIGHT IN POUNDS WITH CLOTHES

Men

Feet and inches with shoes

Age	5-0	5-1	5-2	5-3	5-4	5-5	5-6	5-7	5-8	5-9	5-10	5-11	6-0	6-1	6-2	6-3	6-4	6-5
16	109	111	114	117	120	124	128	132	136	140	144	149	154	159	164	169	174	179
18	113	115	118	121	124	128	132	136	140	144	148	153	158	163	168	173	178	183
20	117	119	122	125	128	132	136	140	144	148	152	156	161	166	171	176	181	186
22	119	121	124	127	131	135	139	142	146	150	154	158	163	168	173	178	183	188
24	121	123	126	129	133	137	141	144	148	152	156	160	165	171	177	182	187	192
26	123	125	127	130	134	138	142	146	150	154	158	163	168	174	180	186	191	196
28	125	127	129	132	135	139	143	147	151	155	159	164	170	176	182	188	193	198
30	126	128	130	133	136	140	144	148	152	156	161	166	172	178	184	190	196	201
32	127	129	131	134	137	141	145	149	154	158	163	168	174	180	186	192	198	203
34	128	130	132	135	138	142	146	150	155	160	165	170	176	182	188	194	200	206
36	129	131	133	136	139	143	147	151	156	161	166	171	177	183	190	196	202	208
38	130	132	134	137	140	144	148	152	157	162	167	173	179	185	192	198	204	210
40	131	133	135	138	141	145	149	153	158	163	168	174	180	186	193	200	206	212
42	132	134	136	139	142	146	150	154	159	164	169	175	181	187	194	201	208	214
44	133	135	137	140	143	147	151	155	160	165	170	176	182	188	195	202	209	215
46	134	136	138	141	144	148	152	156	161	166	171	177	183	189	196	203	210	216
48	134	136	138	141	144	148	152	156	161	166	171	177	183	190	197	204	211	217
50	134	136	138	141	144	148	152	156	161	166	171	177	183	190	197	204	211	217
52	135	137	139	142	145	149	153	157	162	167	172	178	184	191	198	205	212	218
54	135	137	139	142	145	149	153	158	163	168	173	178	184	191	198	205	212	219

Women

Age	4-8	4-9	4-10	4-11	5-0	5-1	5-2	5-3	5-4	5-5	5-6	5-7	5-8	5-9	5-10	5-11	6-0
16	102	104	106	108	109	111	114	117	120	124	128	132	136	139	143	148	153
18	104	106	108	110	112	114	117	120	123	126	130	134	138	141	145	150	155
20	106	108	110	112	114	116	119	122	125	128	132	136	140	143	147	151	156
22	107	109	111	113	115	117	120	123	126	129	133	137	141	145	149	153	157
24	109	111	113	115	117	119	121	124	127	130	134	138	142	146	150	154	158
26	110	112	114	116	118	120	122	125	128	131	135	139	143	147	151	155	159
28	111	113	115	117	119	121	123	126	130	133	137	141	145	149	153	156	160
30	112	114	116	118	120	122	124	127	131	134	138	142	146	150	154	157	161
32	113	115	117	119	121	123	125	128	132	136	140	144	148	152	155	158	162
34	115	117	119	121	123	125	127	130	134	138	142	146	150	154	157	160	163
36	116	118	120	122	124	126	128	131	135	139	143	147	151	155	158	161	164
38	117	119	121	123	125	127	130	133	137	141	145	149	153	157	160	163	166
40	119	121	123	125	127	129	132	135	138	142	146	150	154	158	161	164	167
42	120	122	124	126	128	130	133	136	139	143	147	151	155	159	162	166	169
44	122	124	126	128	130	132	135	138	141	145	149	153	157	161	164	168	171
46	123	125	127	129	131	133	136	139	142	146	150	154	158	162	165	169	172
48	124	126	128	130	132	134	137	140	143	147	152	156	160	164	167	171	174
50	125	127	129	131	133	135	138	141	144	148	152	156	161	165	169	173	176
52	125	127	129	131	133	135	138	141	144	148	152	157	162	166	170	174	177
54	125	127	129	131	133	135	138	141	144	148	153	158	163	167	171	174	177

because of special tastes on the part of the patient. No amount of palaver can evade the fundamental fact that the calories, not necessarily the bulk, must be cut down below existing habits, and that new habits must be formed.

DIABETES

Diabetic diets.—In 1928 Joslin, the leading exponent of diabetes in this country wrote:

It is only within half a generation that diets have been accurately controlled for months and

years and the quantities of carbohydrate, protein and fat recorded, and only within the last twelve years that the total quantity of food has been at all closely limited. In consequence it is only to-day that we are in a position to compare the effects of various diets, only to-day that we can begin to discuss how, for instance, it is best to distribute a given intake between the three foodstuffs.

Almost every physician treating diabetes more carefully than by simple omission of bread has used a different method. Some of these exhibit material differences; most are variations of existing plans of greater or less antiquity. All are fairly complex, with the result that patients, and even their medical advisers who see only occasional diabetic patients, are needlessly confused. Furthermore, the vast number of variations render comparisons of the results extremely uncertain. An immediate need would therefore seem to be the definition of a few types of diet, into which current methods may be grouped somewhat categorically. This grouping would simplify understanding of the principles involved, and make possible analysis of the consequences of emphasis on one or other of these principles. Such an attempt at definition will accordingly be presented, but first we must explain a few of the principal peculiarities of the chemical metabolism in diabetes.

When carbohydrate has been digested in the intestine and absorbed through the intestinal wall and into the blood stream it is in the simplest form of sugar, called glucose, grape sugar or dextrose. To start this burning we must have a match. In the body this match is a secretion from certain cells in the pancreas which are called the islands of Langerhans because they were discovered by that investigator and, under the microscope, looked like distinct islands of one kind of cell in the midst of the already known cells which secrete the various other digestive juices; this secretion is called insulin. If the pancreas is injured, by infection or other causes, enough to cause depletion of the insulin, the result is diabetes. It is estimated that one unit of insulin burns about two grams of glucose. If reduction of the carbohydrate in the diet does not make the urine sugar-free, then insulin made from animals must be taken by injection. This is much less trouble and annoyance than would be expected.

Just as a certain amount of insulin is necessary to burn a certain amount of glucose, so a certain amount of glucose is necessary to burn the fat completely, so that no waste fat will be left over to form poisonous fatty acids in the blood and cause coma. It is estimated that one gram of glucose burns about 1.5 grams of fatty acid.

In diabetes it is generally necessary to reduce the total calories just as in obesity, but it is also important to rearrange the distribution of carbohydrate and fat. When the carbohydrate in the diet is cut down, the shortage may be made up by the body changing into carbohydrate 58 per cent. of the protein and 10 per cent. of the fat digested. Thus in calculating the total glucose of the diet which must be balanced by insulin, either that made by the patient in his own body or taken by injection, we must include these available supplies, supposing the diet consists of carbohydrate 84 grams, protein 61 grams, fat 94 grams:

Carbohydrate	84 grams
58 per cent. of protein, *i.e.*, 58 per cent. of 61 =	35.4 grams
10 per cent. of fat, *i.e.*, 10 per cent. of 94 =	9.4 grams
Total available glucose	128.8 grams

The energy requirements of the body are supplied entirely by the burning of the food we eat. This food is divided chiefly into three kinds: (1) Carbohydrate, which is mostly of vegetable origin: sugars, starches, grains, cereals, fruits; (2) protein, which is mostly of animal origin: meat, fish, eggs, milk, cheese; (3) fat, which comes partly

from vegetable sources: olive oil and cottonseed oil, and partly from animal sources: butter and lard.

The amount of this energy is measured in calories, just as butter is measured in pounds. A calory is the quantity of heat necessary to increase the temperature of 1 liter (1.06 quarts) of water 1 degree Centigrade. Food when burned in the body gives off heat in the following amounts:

1 gram of carbohydrate yields	4 calories
1 gram of protein yields	4 calories
1 gram of fat yields	9 calories
1 gram of alcohol yields	7 calories

Definitions of type diets in health and diabetes.—Suppose we have in bed before us a patient weighing, after subtracting for clothing, 61 kilograms (134 pounds). Her protein should be about 1 gram per kilo, *i.e.*, 61 grams. Her calory need, since she is at rest, will be satisfied by about 23 calories per kilo body weight, *i.e.*, 23 x 61 or about 1,400 calories. Diets which are alike in these two respects may be called iso-caloric (equal calory) and iso-protein. Of such diets we now present four types which seem to us of distinct interest as illustrating the seesaw or inverse relationship between the distribution of carbohydrate and fat: when one goes down, the other goes up; when the carbohydrate is lowest the fat is highest, and *vice versa*. The figures are briefly shown in Table III and Fig. 1.

TABLE III

DIETS IN HEALTH AND DIABETES

Type of diet	C	P	F	Cal.	Ratio FA : G
Low carbohydrate diabetic	41	61	112	1416	1.5
Average diabetic	84	61	94	1426	0.9
Normal	128	61	75	1423	0.5
High carbohydrate diabetic	139	61	70	1424	0.3

SOME OTHER MEDICAL ASPECTS OF DIABETES MELLITUS

Definition.—Diabetes is a disease in which part of the food is not utilized and appears as sugar in the urine.

Frequency of the disease.—Among the hundred million inhabitants of the United States there are supposed to be about one million diabetics. Also among the annual number of deaths in this country those from diabetes make up about 1 per cent. Diabetes ranks about tenth among causes of death; among the commoner causes the best known are cancer, heart disease, kidney disease, pneumonia, tuberculosis and violence. In other countries the frequency of death as reported varies considerably, ranging from 0.1 per cent. in Japan to 3.6 per cent. in the Netherlands. How far these differences are due to racial characteristics and how far to accuracy of statistics is unknown.

Age at onset.—Half of all diabetics show onset of the disease between 40 and 60 years of age. The youngest patient reported was 2½ months old at onset. The relative frequency of onset in the successive decades of life is shown by Joslin's tabulation based on 5,086 patients seen by him.

Age	1–10	10–20	20–30	30–40	40–50	50–60	60–70	70–80	Total
Per cent.	5	7	9	13	25	26	13	2	100

In the first ten years of life the affliction is seen to be relatively rare, being about 5 per cent. of the total. This is fortunate because the disease is more severe in children than in adults. However, we no longer feel alarmed at the diagnosis in a child, because: (1) Insulin has made possible adequate food for growth and activity. (2) The child's preference for plain foods and the foods he knows makes good dietary habits and diet measurement easier than for the

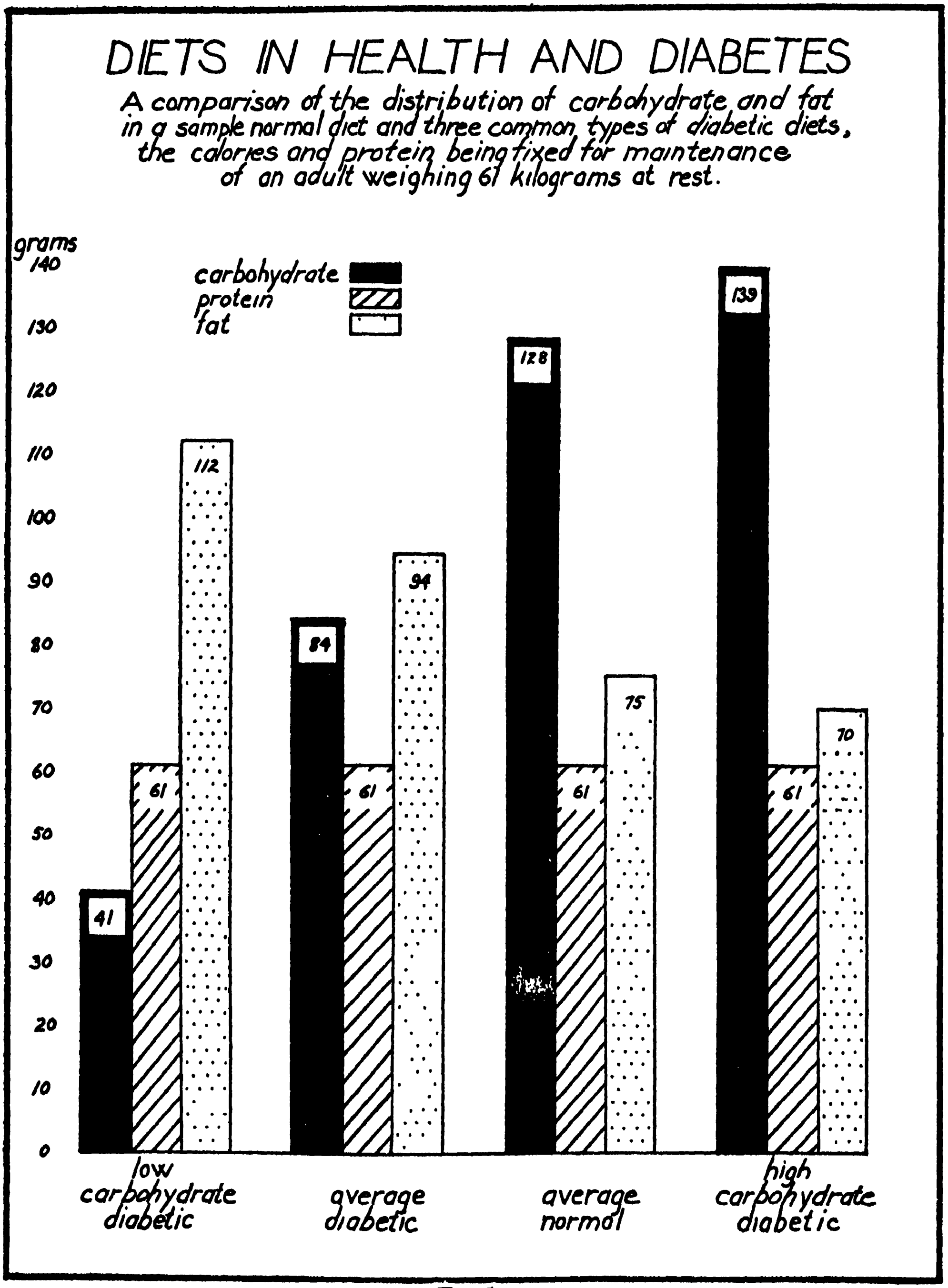

DIETS IN HEALTH AND DIABETES
A comparison of the distribution of carbohydrate and fat in a sample normal diet and three common types of diabetic diets, the calories and protein being fixed for maintenance of an adult weighing 61 kilograms at rest.
grams
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
carbohydrate
protein
fat
41
61
112
84
61
94
128
61
75
139
61
70
low carbohydrate diabetic
average diabetic
average normal
high carbohydrate diabetic

FIG. 1

adult who so often expects great variety. (3) Children are so much more adaptable than adults.

A diabetic child usually looks as if in perfect health. It is a remarkable fact that diabetic children are often unusually intelligent, standing high in their classes.

Diagnosis.—Early recognition is ten times as common to-day as it was 50 years ago. This is due to routine urinary testing, whether as part of examination for life insurance or health supervision. Such routine tests can reveal the disease months before the advent of symptoms such as thirst, getting up at night, loss of weight, dry skin or itching. Early diagnosis is unquestionably the best hope of recovery in this as in other diseases.

Treatment.—The determination of the sugar in the blood is useful, but the main gauge of successful treatment in ordinary practice is the freedom of the urine from sugar. This fact must be insisted upon, over and over again. As long as the urine is not sugar-free the patient is liable to complications varying from pimples, boils, itching, muscle aches, arteriosclerosis; to ulcers, gangrene, cataract, coma and even death. Small amounts of sugar are far too often neglected because the patient feels well.

The patient's help is indispensable for successful treatment, and this means: (1) Regular visits to the physician, at least once in 6 months; special visits at any time that sugar appears in the urine and can not be eliminated by the patient within three days, and immediate notification of the doctor in case of fever, acute digestive or other upsets. (2) Bringing on each visit to the physician a list of the articles of food eaten during the preceding 24 hours, not forgetting to write down the approximate amounts. (3) Regular tests for sugar with Benedict's solution, often enough to keep sugar-free; this varies according to the severity of the disease from twice a day to twice a month. (4) Getting weighed regularly, generally once a week. (5) Weighing articles of food whenever guessing proves insufficient to produce sugar freedom. (6) Taking insulin if this weighing also proves insufficient, and also in case of certain complications.

Insulin.—At this point it is well to remark that insulin offers no sudden cure like a surgical operation, as some fancy and as we all wish were the case; hence when insulin treatment is discontinued the diet must often be decreased somewhat, and on this the physician should be consulted. Furthermore, there is doubtful benefit and often real danger in taking insulin unless the patient is both willing and able to estimate the food accurately, otherwise wastage is sure and shock-reactions to be feared. Four fifths of diabetics need no insulin except temporarily in acute infections and in surgical emergencies, while the remaining one fifth should not expect to receive much benefit from insulin unless they measure their food intake. Actual calculation of the C–P–F values can be escaped by some patients, but all are better off when they have learned how, even though they may calculate only occasionally, for thus they can make substitutions in diet while traveling or eating elsewhere away from home.

Summary.—Obesity and diabetes alike offer the optimistic aspect that improvement can be promised with a noteworthy degree of confidence to the patient who cares enough about health to "play ball."

"There is no drug as powerful as hope."—*Axel Munthe.*

THE DECLINE IN BIRTH-RATE OF THE FOREIGN BORN

By Dr. JOSEPH J. SPENGLER
UNIVERSITY OF ARIZONA

JUST eighty years ago Dr. Jesse Chickering observed that the foreign-born women of Boston were bearing far more children than the native women. "The whole increase from the excess of births over deaths for these two years [1849–1850]" he observed, "has been among the foreign population." Not many years later it became generally feared that immigrant women, through their greater fecundity, would inundate New England with foreign stock. The natives who, according to John Adams, were "purer English blood—than any other" seemed threatened with displacement at the hands of the Irish, the Germans and others.

In the present paper I shall sketch briefly the growth of this fear of the effects of a relatively greater foreign fecundity. I shall then present the available data and show whether or not the native American will eventually succumb to the foreign stock as a result of the reproduction struggle still going on.

I

The first data we have concerning the comparative birth-rates of native and foreign-born women were obtained in the census of Boston in 1845. Prior to the forties there was little immigration into the United States. Most of those who came were English and hence hardly distinguishable from the natives. In the forties, however, many Irish fled from famine-stricken Erin and many Germans hurried from revolution-torn Germany. The immigrant population, therefore, became distinguishable from the native population and was so registered in the records of the day, such as the census, the birth registration reports, etc. One notes accordingly that in Boston in the year 1845 there were 80 births to each 1,000 foreigners aged more than twenty years. The corresponding native rate was 41, or but half the foreign rate. In the Broad Street section of Boston 212 children were born in 1845 to 2,131 inhabitants, mostly foreign born. That is, one child was born for each five women. Needless to say the burial records testify to an exceptionally high infant mortality rate among the foreign born.

Fear of superior foreign fecundity was not expressed, however, until the births to foreign parents began generally to be distinguished from births to native parents. This distinction was made in Massachusetts in 1848, and somewhat later in the other New England states, in Michigan and in Indiana. Dr. Chickering's expression of fear was repeated in the late eighteen sixties by Dr. Nathan Allen, of Lowell, Massachusetts, a prolific writer on the alleged decline of the native stock. Allen charged that the native stock was dying out through failure of native women to bear children while at the same time the newly arrived foreigners were multiplying rapidly. New England, therefore, seemed doomed soon to be overrun by immigrant stock.

In 1869 the compiler of the Massachusetts registration report sanctioned Allen's statement by remarking that the English stock, meaning primarily the natives, is "likely to be at no very distant day outnumbered by the Irish, the Germans and the French Canadians."

Because of the increasing interest in the problem the census enumerators in the state censuses of New York, Massachusetts, Rhode Island and Michigan, and in the federal censuses of 1890, 1900 and 1910, were instructed to inquire of women the number of children they had borne. The material obtained in Massachusetts, Rhode Island and Michigan showed conclusively that foreign-born women bore more children than did the native women. The Rhode Island data indicated further that while Jewish women were more fecund than Catholic women, and Catholic women more fecund than Protestant women, the foreign-born women of each creed averaged more children than did the natives. As is sometimes characteristic of the federal census, only a small portion of the material secured was published. It was made evident, however, that foreign-born married women in Rhode Island and parts of Ohio and Minnesota bore more children than did the native women, and that native-born women of foreign parentage bore fewer children than foreign-born women but more children than natives of native grandparentage. That is, the birth-rate of the foreign stock gradually becomes Americanized in the course of a generation.

Careful studies by Dr. R. R. Kuczynski and Allyn Young confirmed some of the conclusions stated above and indicated also that foreign-born women bore more children at all ages than did native women of corresponding ages.

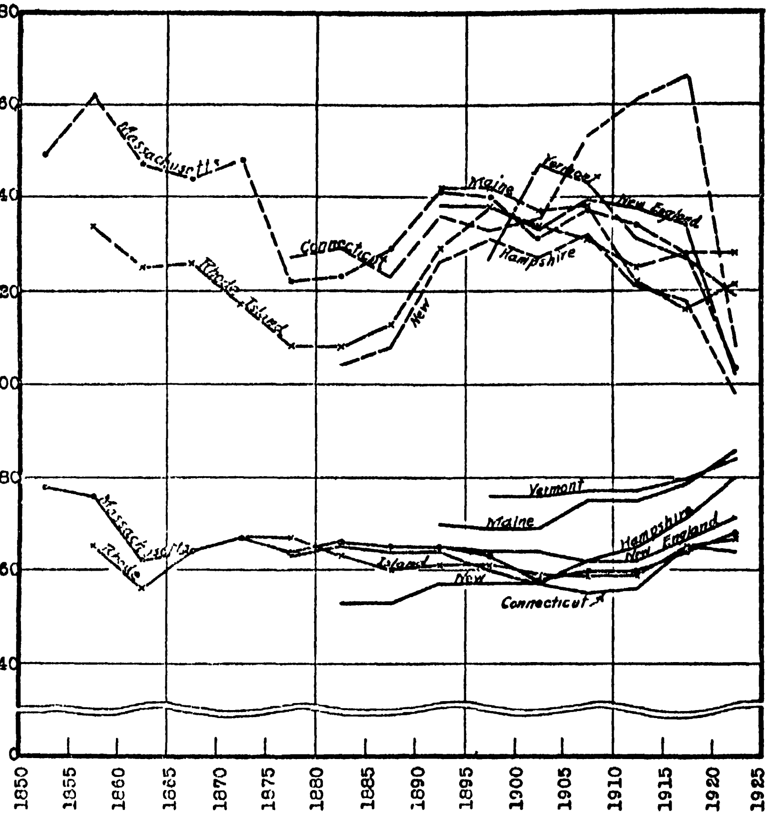
It was but a step from noting that foreign-born women bore more children than natives to arguing that the influx of the foreign-born immigrants was the cause of the decline in the American birth-rate. General Francis Walker, a prominent economist and a superintendent of the federal census, developed this argument in an article in *Forum*, 1891, entitled "Immigration and Degradation." Walker contended that the coming of the immigrants shocked American sentimentalities and initiated an "industrial competition" from which "the American shrank. If the foreigners had not come the native element would long have filled the places the foreigners usurped." In other words, Walker was contending that, had there been no immigration, the American population would have been just as numerous as it is to-day. In place of the 53 millions alleged to be of immigrant stock there would have been 53 more millions descended from native American stock. That is, had there been no immigration into the United States the three million whites of 1790 would have increased to 95 millions by 1920, a geometrical rate of increase such as Malthus alleged was true of eighteenth century America.

Although such leading authorities as Commons, Bushee and Fairchild support Walker's theory in large part, E. A. Goldenweiser has refuted it by showing that the real causes of the decline in the American birth-rate are but remotely related to immigration.

Thus far I have shown that it has long been contended and frequently substantiated that foreign-born women were bearing more children than native women. I shall now examine briefly the causes of this difference and then demonstrate that the foreign-born women will soon be bearing no more children than the natives.

II

In the accompanying chart are traced the trends in the average number of children born to each 1,000 native and to each 1,000 foreign-born women of child-bearing age in the New England states. The rates delineated in this chart are taken from a monograph by the writer entitled "The Comparative Fecundity of the Native and of the



NATIVE AND FOREIGN FERTILITY IN NEW ENGLAND

Foreign-Born Women of New England," published this year as one of the Brookings Institution Population Studies under the supervision of Dr. Robert R. Kuczynski.

The solid lines depict the fertility of the native women; the broken lines depict the fertility of the foreign-born women. If we examine the lines depicting the trend in native fertility we find that in the two states for which we have evidence, Massachusetts and Rhode Island, the Civil War occasions a sharp decline in fertility. Thereafter in each of these states native fertility remained practically unchanged. In the other four New England states and in the entire New England area native fertility has increased in the present century. This conclusion is contrary to the customary assertion that the native birthrate is declining in New England.

The broken lines representing foreign fertility depict a remarkable decline in the fertility of foreign-born women. The most striking decline has taken place in Massachusetts. There we find foreign fertility only five eighths as great since 1920 as during the five years preceding the Civil War. In other states the decline, while not so great as in Massachusetts, has been striking. The foreign-born women living in New England during the five years after 1920 averaged only three fourths as many children as did the foreign-born women during the last decade of the nineteenth century. In short, foreign fertility has decreased 26 per cent. in 30 years.

The sharp decline in foreign fertility

coupled with the failure of native fertility to continue to decline means, as examination of the chart makes plain, that in the near future the native rates will be no lower than the foreign rates. In the chart this is indicated by the fact that the broken lines and solid lines are converging toward each other.

This convergence within the last few decades may be illustrated in another fashion. At one time foreign fertility was more than twice as high as native fertility in every state but Vermont. Yet, since 1920, for New England as a whole, foreign-born women have been averaging only three sevenths more children than native women. The data for New York, Indiana and Michigan indicate a similar convergence. We may conclude, therefore, that in nine states the differences between native and foreign fertility are rapidly disappearing.

III

Thus far we have demonstrated that, contrary to general opinion, native fertility has not only not decreased in New England but has actually increased. We have shown further that foreign fertility has steadily declined and will soon be as low as that of the natives. In the present section it will be indicated that birth control is the sole explanation of the decline in foreign fertility.

The main reason that the fertility of the foreign-born exceeds that of native-born women is the fact that a much larger percentage of the foreign-born women of child-bearing age are living in the married state. More than 99 per cent. of children are born to women aged from 15 to 49. The number of children a population can bear, therefore, depends upon the proportion in that population of women aged 15 to 49, and in turn upon the proportion of women aged 15 to 49 who are married. During the last half century 47 of every 100 native women, aged 15 to 49, have been married. In 1890 of every 100 foreign women of this age 54 were married. By 1920 the proportion had increased to 72.

On the grounds of marriage alone, in 1890 foreign fertility should have been 15 per cent. higher than native fertility; by 1920 foreign fertility should have exceeded native fertility by about 50 per cent. Yet whereas in 1890 foreign fertility was twice as great as native fertility, by 1921–1925 it was only 44 per cent. greater than native fertility. In short, whereas we should have expected foreign fertility in 1920 to be 33 per cent. higher than foreign fertility in 1890, we find instead a sharp decrease of one fourth.

The only explanation of this sharp decline in foreign fertility lies in an increased resort to birth control on the part of foreign-born women. Advocates of birth control can, as a reading of the *Birth Control Review* will indicate, offer many individual cases of foreign-born women who unfortunately know nothing of the practice of birth control. Nevertheless the figures I present clearly prove that an increasingly larger proportion of foreign-born women are voluntarily restricting the number of children. Possibly, too, a great many are resorting to abortion. It has, in fact, frequently been asserted that between one half million and two millions of abortions are performed annually in the United States. Proof of this alleged high frequency of abortion is, in the nature of the case, not possible.

That foreign-born women living in New England, New York, Indiana and Michigan are practicing birth control or resorting to abortion in nearly the same degree as native women is readily demonstrable. Since we know that American married women are restricting the number of births it follows that foreign-born married women must be doing likewise if it can be shown that foreign-born married women are bearing, on the aver-

age, few more children than native married women. In the years 1919 and 1920 foreign-born married women in New England bore on an average only 26 per cent. more children than did native married women. By 1922 this margin had fallen to 18 per cent. in Connecticut and to still less in Vermont, New Hampshire and Rhode Island. In New York in 1922 foreign-born married women bore on an average only 14 per cent. more children than did native married women; in Indiana, 8 per cent. more; in Michigan the rates for native and foreign-born married women were nearly identical. In other states the same general trend is noted in 1922, the last year for which data are available. In that year in the United States Registration Area (27 states and the District of Columbia) the number of births per 1,000 native married women, aged 15 to 44 years, was 155; per 1,000 foreign-born married women of corresponding age, 159.

IV

Our argument as presented in the earlier parts of this article may be briefly summarized. Seventy-five years ago foreign-born women were bearing more than twice as many children per woman as were native women. However, foreign-born women gradually began to copy the practices used by their American sisters to restrict the number of children. Consequently foreign fertility steadily declined. Native fertility, on the contrary, has either remained constant or has actually increased in New England and possibly in certain other states. As a result of this decline in foreign fertility coupled with the cessation of decline in native fertility to-day we find foreign fertility nearly as low as that of the natives. In fact, it probably will soon be as low. At present foreign fertility exceeds native fertility chiefly because more foreign-born women marry. Since we know that American married women restrict the birth-rate and since we find that foreign-born married women average few more children than do native married women it follows that in a number of states foreign-born women practice birth control and resort to abortion as frequently as do native women.

From the data we have presented and analyzed we may draw several more philosophical conclusions. The situation we have traced in New England is analogous to the situation in Europe several decades ago and to the so-called eugenic situation to-day. For nearly three quarters of a century French nationalists, contrasting the low birth-rate in France with the high birth-rate in Germany, Italy and other parts of Europe, were aghast. Would France not be destroyed by the greater fecundity of foreign peoples? Levasseur in 1890 suggested that all European birth-rates would tend to equilibrium, to equality, in the course of time. Dr. R. R. Kuczynski, in his "The Balance of Births and Deaths," has proved that Levasseur was right. To-day European birth-rates are rapidly approaching equality.

Eugenists have frequently argued that Western civilization would be destroyed through the multiplication of the unfit at the expense of the fit. Yet to-day statistics of such countries as Sweden reveal that in some instances the abler classes are actually bearing more children than the less able classes.

Essentially, therefore, birth control is a great leveler. It has promoted equality in the birth-rates of the native and the foreign-born stocks of America. It has equalized the birth-rates of various European peoples. It has been adopted by the allegedly less able classes and has thus partially solved the eugenic problem on the negative side.

From the fact of the general adoption of birth control in Europe and by the

foreign-born immigrants in the United States it is apparent that the desire to restrict births is an essential aspect of what is called Western civilization. Arsène Dumont and Leroy-Beaulieu drew attention to this in the last decade of the nineteenth century. According to Leroy-Beaulieu, "Civilization, which is really the development of material ease, of education, of equality and of aspirations to rise and to succeed in life, has undoubtedly conduced to a diminution of the birth-rate." Civilization, as we understand it, means also that a child has become an economic and social liability rather than an asset; that in the new material scale of values the child has been replaced by the Ford; that to-day the pecuniary value of the things desired exceeds the pay envelop more than ever before; that the present view is not other-worldly, but this-worldly.

Oswald Spengler, in his "Decline of Western Civilisation," asserts that "when the ordinary thought of a highly cultivated people begins to regard 'having children' as a question of pro's and con's, the great turning point has come." The beginning of the end is at hand. As evidence he points to Hellas, to Rome, to India, to China. It has been statistically demonstrated that because of an insufficiency of births the populations of most of the European and English-speaking countries are dying out. May one therefore conclude that the American population will ultimately die out?

The data we have presented seem to yield a negative answer to the question raised in the preceding paragraph. For fifty years native fertility has been very low in New England, but for fifty years native fertility has not decreased. It would appear, therefore, that native fertility has reached as low a level in New England as will ever be experienced there. And from this one might generalize that when fertility in other parts of the United States has become as low as it has been in New England there will be no further decline. But as Corrado Gini and others have suggested, the American people may be experiencing a decline in their natural capacity to bear children, a decline that has merely been halted temporarily by the infiltration of foreign blood. If Gini is right the American along with the Teuton may be doomed to disappear. On the contrary, if the limit of the decline in fertility has been reached then America will shortly have achieved a stationary population, possibly the only means of escape from the Malthusian devil of overpopulation and the Spenglerian specter of race suicide.

CURANDEROS IN OAXACA, MEXICO

By Dr. ELSIE CLEWS PARSONS

Like so many early Spanish customs or institutions, the institution of *curandero* or village curer is wide-spread in Mexico. Recently in the state of Oaxaca, more particularly among the Zapoteca-speaking towns, I have been making a study of these Spanish-Indian doctors and diviners who might be called shamans in an out-and-out Indian culture, or soothsayers and quacks in more sophisticated circles.

All *curanderos* are good Catholics, like most of the townspeople, maintaining their house altar and in their professional practice addressing the saints. There is no organization among the *curanderos* of a town—rather competition and a tendency to professional jealousy. They are men or women, *curanderos* or *curanderas*, and in their methods, whether of curing or divining, there appears to be but one distinction as far as sex is concerned, the *curandera* commonly functions as midwife. Some *curanderas* do not, just as some *parteras* or midwives are not considered *curanderas*. In other respects also the practice of one *curandero* varies somewhat from that of another. Isidora, of Mitla, is herb doctor and midwife as contrasted with Agustina Gonzalez who sucks for witchcraft and divines with corn. Urbano, of Mitla, is an herbalist, but he also "sucks." María García practices a method of divining with corn which she learned at Cuilápam, a Mixteca-speaking town. This is her single professional accomplishment. Margerita Hernández, of San Baltazar in the mountains, divines not with corn but with cards, and she "sucks." Josefa, of Zaachila, a midwife, also "sucks." José Martínez, of San Miguel, Alvarrados, another mountain town, divines with corn and cures with herbs, but does not "suck." "*Chupando es mentira*" (sucking is falsehood), opined the herbalist of Cuchitan, on the Isthmus.

Sucking out the object the witch has sent into the body is a very wide-spread Indian practice, and I believe the contemporary usage in Oaxaca is a survival from pre-Conquest times, even if the setting of the cure is Spanish. The witch-sent object, *chizo* (probably from *hechizera,* witchcraft) or *chaneca,* a term less commonly used, may be thorns, glass, stones, bones or anything noxious to the flesh. At Zaachila, cramps in my legs were diagnosed as caused by red ants in the abdomen. Among the Pueblo Indians of New Mexico, by the way, ants within the body is a very common diagnosis of skin eruptions.

At Zaachila I was not treated, but at Mitla I was sucked—for headache, caused not by *chizo,* but by *aire,* that perplexing source of sickness which is sometimes referred to as if it were a spirit of the air[1] and at other times as if nothing more than a draft.

"Why do you think so much?" asked Agustina. "You think and then *el aire se pega,* the air catches you, you hear a drum in your head. *Sola?*"

"Si."

"*Su marido?*"

"*Muerto.*"

"*Es razón por piensar.*"

As for "the air," she would suck to get it out.

"But it hurts. You may not be able to stand the pain."

"Draw blood?"

"No."

[1] In Morelos and Puebla there is no mistaking the supernatural character of *los aïres.* See Robert Redfield, "Tepoztlan," Chicago, 1930; E. C. Parsons, "Folklore from Pueblo," *Journal American Folk Lore,* in proof.

Reassured, for Agustina's remaining teeth were black, I gave her the five centavos she requested in order to send the little girl for a half bottle of *aguardiente.*

We talk. Agustina was not born in Mitla, but in Copainala, Tabasco. Her father was *curandero,* her art was *una herencia*—the only instance I encountered of coming to the profession through inheritance—and her father's brother was a priest. From this priestly uncle she learned the prayers she used professionally. San Antonio is her special charge, and his picture is, of course, on her altar, together with bits of candle, two vases of freshly cut stock and some egg-shells. Underneath is the copal censer which in religious observance is used almost as much as candles by the Zapoteca-speaking household.

Now Agustina takes a drink, spitting after it, and she urges one on me, to fortify me against the pain. Over the back of my neck she passes her fingers, firmly, then she anoints with oil, and then sucks, in three places, right side, left side and middle. The suction is strong, at the sides of the neck producing some pain. She spits each time into the inner leaves of a corn husk, which she finally burns, and each time before sucking she prays in a low voice, "Dios, Espíritu Santo, San Antonio, make the sickness come out!"

Agustina, of Mitla, and Josefa, of Zaachila, used almost the same method of diagnosis. You held out your two arms, bared; over them from her mouth Josefa spurted some *aguardiente,* a preliminary omitted by Agustina. Your pulse was tested by a thumb on each wrist, then on the arm below the elbow. Agustina vibrated her thumbs as she tested. Again the same form of diagnosis by José Hernández, of Matatlan, when I opined that Eligio, my companion from Mitla, was bewitched, having cramps in his arms. José was not to be fooled by that pair of strong, supple arms. "You only think you have *chizo,*" said the shrewd old man.

Treatment by sucking is generally repeated several times before the *chizo* is extracted and spat into the corn husk. I was present when patients undergoing the treatment called upon Urbano, of Mitla, and upon Margerita, of San Baltazar; but the treatment I was not allowed to see, for reasons obvious enough. Why give an opportunity to a disinterested outsider to observe your chicanery?

Urbano's patient was a young man whose right arm and hand had become so stiff he could not close his fingers, a surprising condition explicable only as due to *chizo.* The witch would be a fellow townsperson, but no effort to identify him or her would be taken. As far as I could learn no witch baiting ever occurs. Not even at San Blas, Tehuantepec, where the *curandero* himself is described as a witch—he sends the *maldad* into you to have you go to him to suck it out. In other cases, on the Isthmus, doctor and witch were identified.

Margerita's patient was also a young man, suffering from some form of hysteria—he lay for a long time on his *petate* moaning and jerking his legs. His wife held his head, stroking his neck and shoulders. They came from Matatlan, twelve miles or so across the mountain, for the treatments, and later when I rode through Matatlan I heard the story as told by the town gossips. After the young man had left his first wife for a younger woman, he was walking along one night when he was beckoned to by somebody he took to be his former wife. He followed the woman, who led him off to a *barranca* and left him. Ever since he has been stricken.

This hysteric was frightened by a *matlansiwa,* according to Eligio, a being who takes the shape of a man or woman to lead you astray, particularly the shape of some one you have been attached to.

There are other forms of fright, naturalistic forms, generally through animals, a bull, a mad dog, a snake, which also require special treatment. The symptoms are always much the same—sleeplessness, dreams, heaviness on awakening, apathy or listlessness, no ambition, loss of appetite. The symptoms rarely develop at once, but in a month or two, or even in a year or two. To diagnose the cause of fright, copal is burned in water. On the under side of the copal will be found a picture of the cause of fright—a snake, a dog, a drunken man, etc. That the spirit may return, *para que regresa el espíritu,* if the place of the occurrence is not too remote, the *curandera* goes there with the patient, burying an egg, pumpkin seeds and fourteen little *tortillas*—at least this is one form of the offering. In some places a chicken is offered. On the return home the *curandera* beats on the ground with a stick, calling out, *"Ven! Llevantate!"* Now in the house of the patient the two flower vases are removed from the house altar to the ground, and filled with green reeds. Near them is placed some copal in a small bowl of water. The copal is set afire and on it is sprinkled little bits of *shki'bal,* which is the nest of a bee made of grains of sand gummed together with resin. Now the *curandera* takes a mouthful of water from a gourd and spurts the water onto the ground. On the moistened place she makes a cross with her finger-nail. Again she spurts water from her mouth. She slaps her right hand on the cross and then on the chest of the patient, *"Ven! Llevantate!"* Thrice she does this. Then the patient drinks the water from the bowl containing the copal together with an infusion of the herb called *verba de espanto* which has been well ground up and strained.

The *curandera* proceeds to *llamar las cuatro esquinas.* Into each of the four corners of the patient's house she carries a small jar, clapping its mouth with her hand, and calling into it in a low voice, *"Ven! Llevanta! Yo te vengo a traerte. Corre! Ven!"* Thrice she makes the circuit of the corners.

I have been describing Isidora's treatment for fright, *espanto.* In Urbano's treatment there are some other details. The cross traced on the ground is filled with the blooms of hollyhock. With *aguardiente* in his mouth Urbano sucks the patient's arms, passing his lips lightly along the flesh, and he massages the body with *aguardiente.* Into the copal water for the patient to drink, after calling the corners, go a plant which is "stronger" than *verba de espanto,* also, besides the *shki'bal,* a "red bee," probably the bee that makes the nest.[2]

The use of copal and bee nest and possibly the offering at the place of the fright seem to be Indian features, and the notion of sickness from fright, whether or not it is originally Indian, is readily adopted by Indians, witness its prevalence among our Pueblos; but whether the calling in the four corners and the general ideology of the spirit being temporarily lost are Indian or Spanish, I am in doubt. I would like to hear of European parallels, if there are any.

That curing with egg is European there is no uncertainty, particularly in the case of *mal ojo* or *ojo,* the usual reference to the evil eye. I had complained of indigestion to Agustina, so she gave me a raw egg to carry all day next my stomach, as exacting an instruction as ever I had from a doctor. On my return to the house at the foot of the pyramid-perched *calvario*—Agustina's neighborhood together with her house, built with stones from the ruins, are, like her practices, a compound of old and new—Agustina bids me pass my egg over my entire person. Then, holding the egg over a small bowl of water,

[2] It belongs to some genera of the solitary bees. The nest specimen I obtained for identification contained brood cells stored with pollen.

she touches the brim in four places, in sign of the cross, and breaks the egg into the bowl. She exclaims and points to a reddish spot on the egg and to a bubble in the water. The bubble indicates *ojo,* the red spot, stomach trouble affecting the heart. I must return to-morrow for her to rub my stomach with egg and *aguardiente.* The egg she has divined with she is going to bury.

Does Agustina believe in her cures? Probably, at least in part. She is a forceful, self-confident personality, rather kindly, with an eye, however, to her main interest which is her income. But she does not overcharge, according to the townspeople, whereas Urbano, her chief rival, is considered both avaricious and unscrupulous. He believes less in himself. Given his somewhat sardonic humor, I shouldn't wonder if he did not believe in himself at all—except in his ability as charlatan. He looked at me very quizzically indeed when first I asked him if he could suck. "Do you believe in that?" asked his eyes, if not his mouth. His wife, Petronilla, who acts as his assistant, is the avaricious one, and is much the greedier of the two. As for son and daughter, their attitude towards the professional activities of their parents is suspiciously frivolous.

I took Urbano rather lightly myself until one day I saw him treat two infants. His hands were gentle and his manner kindly. One infant had a sore (*granos*) on the cheek, which Petronilla was dressing with a dark green paste. Urbano applies the leaves he has just gathered, and the mother binds up the face and head, quieting the protesting baby by giving it her breast. The baby is very emaciated—a case of *aïre,* the baby has a violent temper, crying a great deal, and at such times *el aïre se pega* and the eruption results. The other infant is fat and healthy looking, but it has been vomiting and so is to be sucked for *ojo.*

"Do you want to suck it?" asks Urbano, the joker.

"No, I would rather see how you do it." He takes a mouthful of the *aguardiente* the mother brought him and spurts it over the child's right arm. With his finger he traces a cross and then, sucking gently, he passes his lips along the fat little arm. Then the same for the left arm. He sucks both sides of the forehead, both sides of the neck and then the chest. After washing his fingers in a gourd of water, he puts them down the child's throat, five or six times he does this, bringing up a little saliva which he washes off. This sucking, by the way, whether for *ojo* or *espanto,* is quite different from that for *chizo,* when something has to be extracted.

On her own healthy grandchild Isidora gave me a demonstration of how she, too, sucked for *ojo.* It was much the same as Urbano's way. Before sucking she massages the child with an infusion of leaves of the *peru* (acacia) and the herb called *ruda,* and then with table oil. For *chizo* Isidora does not suck. To draw blood or pus she uses a cupping glass, bought at an apothecary shop in Oaxaca. Isidora prefers Spanish survival to Indian!

Isidora is quite a different type from Urbano, or from Agustina. She is a nurse *par excellence,* looking after people rather than exploiting them. Taking care of life appeals to her. In her courtyard is a corral of sheep and goats. She keeps a flock of pigeons and much poultry. To see her warm a lamb or kid or quiet a frightened pigeon or scolding hen—the birds are constantly in and out of her room—or give her grandchild a bath, is a pleasure, so firm and gentle are her hands and spirit.

Throughout the profession there is a considerable use of herbs, leaves, roots, etc.,[3] but Isidora's pharmacopeia is much the largest I saw. It contains herbal remedies for indigestion of all kinds

[3] Compare Redfield, pp. 158–160.

—loss of appetite, stomach-ache, constipation, diarrhea—and for headache, bruises, gonorrhea. There are emetics and cathartics, abortives, poultices, ointments; also alleviatives for whooping-cough and measles, two epidemics very fatal to children among the Zapotecas, and even for smallpox.

For rheumatic pains Isidora massages with mountain lion grease. For ant bite she prescribes the saliva of a pregnant woman; for bloody vomit, a cupful of burro blood; for sore eyes, an infusion from the umbilical cord of the new-born, a remedy widely known.

The sweat bath, *temazcal,* is used primarily by the Zapotecas during a confinement, but *curanderos* may prescribe it also for various ailments, in women and men. José Martínez had ordered one for a male patient suffering from earache the day I visited the old man in Matatlan.

Old José was unusually garrulous; he told among other things of how to catch a witch, by spilling the tiny seeds of *Brassica nigra* around the house which the witch has to stay to count, or by transfixing her by throwing water or urine and anthill sand at her. She will confess and die of shame. "If you kill her, you kill her." José also told of the tricks of spiteful lovers, how to make a woman's face break out in pimples or make her dry up and die. José had a patient once with a bad leg which he said had swollen because the young man had turned Protestant.

Isidora is quite as well versed as old José in charms against witchcraft and in spite charms, also in love charms, but I got the impression from her and from others that for such charms the *curandero* is not much appealed to, they are a matter of general knowledge or of knowledge within the family.

Divination is a distinctive function of the *curandero.* It appears to meet a wide-spread and deep-seated need in Oaxaca[4] and probably throughout Mexico. Cards are, I suppose, the most common medium, but excepting the divining with basket and scissors which I saw at San Blas, Tehuantepec, the method I made a point of observing was throwing corn (*tirar mais*).

The *curandero* of San Blas, Benino Cabeza or Tío Niño, I had heard of in Mitla; once Eligio had gone to him for news of a horse lost on a trading trip. Benino told Eligio that the horse had been stolen and in his mirror he showed the thief. I had lost some beads, I told Benino, and I wanted him to *sacar la suerta de canasta.* But Benino urged cards, and got out a manual of necromancy, reading me a paragraph about Solomon and the Queen of Sheba to divert me from the idea of the basket method. It was not until I made him laugh by describing scissors with my fingers, I had forgotten the Spanish word, that he gave in. "*Que alegre!*" he chuckled, patting my knee. Into the center of the under side of a flat basket he sticks the points of a pair of scissors, then, placing his thumbs not through but under the finger loops of the scissors, he raises the basket which by an imperceptible motion of his thumbs on the scissors he makes revolve, letting it drop from his thumbs when as he talks he mentions the answer desired. "Were the beads lost in the house or in the street?" At *street* the basket drops. "Were they stolen or merely lost?" *Lost,* drops the basket, and so Benino after all does not have to show me the mirror trick, the clever rascal! Before each spin of the

[4] Because I wore a kerchief around my head instead of a hat, I was frequently taken for a fortune-telling gypsy, Húngara, and asked to divine, generally about love affairs. I recall especially a pitiful appeal by a woman sitting next me on a park bench in Oaxaca. Her *señor* after living with her seven years and begetting a daughter, left her two years ago. She was *muy triste,* she said, thinking of him all the time. She wanted me to divine for her if he would return to Oaxaca and to her.

basket Benino mutters a prayer, addressing *"El Espíritu de Canasta*, you who know all parts of the world."

Benino assured me that his basket method of divining was not learned from the book, nevertheless all of it is obviously Spanish. On the other hand, divining with corn, a practice unfamiliar on the Hispanicized isthmus and in the more Spanish parts of the country, is, I incline to think, of pre-Conquest provenience. In general the method of throwing corn, *tirar maís*, is to shell out a number of grains from an ear of corn and throw them on to a *petate*, divining from the figures or positions the grains make or take, or when the grains are blackened on one side, from the whites or blacks that fall uppermost.

In this general scheme there are many minor deviations of some interest. José Hernández, of Matatlan, shells out four grains of white corn, blackening one side of each with soot collected into a piece of corn husk from the bottom of a cook pot. He throws the grains onto the *serape* he has spread out, throwing four times to answer my question—was I to marry again? Yes, said the corn, and it would be a good marriage.

"How does the corn show this?"

"Because the grains turn up mostly black."

I tell Eligio to put a question and he asks whether he has any enemies. None, again because the grains turn up black. This time old José has thrown six times. José had been out on a case when we called, and as they were preparing the sweat bath, the fire sparked out—a sign of visitors, said José, and just then his wife arrived to tell him we were calling at his house. He believed the fire could divine and as he believed in the fire, just so, he said, he believed in the corn. And I think he did.

José Martínez, of San Miguel Alvarrados, was far less convincing, for one thing because he talked continuously to his wife about the meaning of the throws, to create an atmosphere of credibility. He shells fourteen grains from an ear of yellow corn, using a bit of charcoal to blacken one side or rather the notch in the grain. He places the grains on the *petate*, black sides up, and over them makes the sign of the cross, saying, *"En nombre del Padre,"* etc. Then looking towards his altar, he crosses himself. He gathers the grains into his left hand, breathes out on them and mumbles a prayer. I catch references to La Trinidad, San Pablo de Mitla, San Antonio. He transfers the grains to his right hand, shaking it and throwing onto the *petate*. Yes, my children are all well, several throws make this clear. This time Eligio has an enemy—because he is with *esta señora.* He should be very careful. Eligio learns later from another townsman who had listened in that José was under the impression that he, Eligio, was my *novio,* and the enemy referred to was a suppositious husband.

In San Baltazar I was in luck when we called on Rosa Hernández and asked her to throw the corn. The unhusked ear she took from her store proved to be a double ear, at which she and her son exclaimed, and she treated the corn ear as I had seen her behave towards the great Cross of Mitla, when I first met her on a pilgrimage, holding first the right cheek to the corn ear and then the left, and then kissing it. Plainly this kind of double ear which is used for seed corn and is a token of abundant crops has a fetichistic or sacrosanct character. At San Domingo Alvarrados I found that the flour for the bread offering made to La Tierra in time of drought was made from the double ear. (In Zuñi, New Mexico, the double ear is referred to as mother and child, and at Laguna it is fed to stock to make them reproduce generously.)

Well, from her double ear of corn

Rosa shells out twenty-two grains; half she places in my right hand and half in my left, crossing each hand. She directs me to cast each handful into a small bowl which she places on her altar. She makes the sign of the cross on the rim of the bowl and then waves it around all the pictures of the saints on the altar. From the pictures she motions towards the bowl with both hands—the same drawing-in motion I had seen her making at the cross, from the four directions. Removing the bowl from the altar to the *petate* she repeats the drawing-in motions—from the altar, from the north side, from the west. Now she covers the bowl with another and shakes the grains up and down, three times. She uncovers the bowl and studies the grains intently. She pours all the grains into my right hand and bids me make the throw onto the *petate*. Several times I have to throw, and I am told that my mother and one son are thinking of me, that I am going home soon, that I am to live a long time. As for Eligio, poor fellow, he has enemies this time, too, and his wife is grieving about him. For him the whole ritual had been repeated and fresh grains shelled, sixteen.

Evidently this was a haphazard number as it was in all the other cases of divination I saw, except the divination by María García, the mode of which she had learned among the Mixtecas.[5] María has to have exactly fourteen grains to compose her divinatory picture (Fig 1).

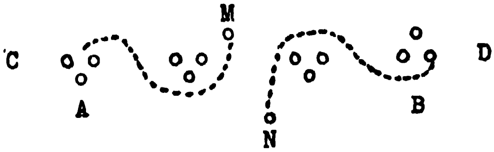


FIG. 1.

The grains are from an ear of black corn and she groups them with precision on a very small *petate* in front of her. She carries the single grain at M to the group at A along the curve indicated, and the grain at N to the group at B. The four now at B she carries to C, and the four at A to D. From the group at C she picks up one grain, placing it near C, and to it she adds one grain from the group at D, leaving Fig. 2. She holds

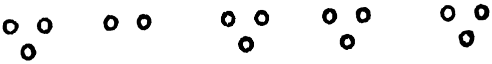


FIG. 2

her mouth down near D and blows on the grains to make them scatter. . . . I ask three questions. Are my children well? Shall I remarry? Is my married daughter to get a divorce? For each question she rearranges the grains and blows, and she asks a few questions herself. How many children have I? How long widowed? Has my daughter children? The corn tells her that two sons are sad, thinking of me; the third is selfish and disobedient. They are going to abandon something important; I should go back to look after my affairs. I have a lover the children do not like. I had better not marry him, life with my family would be unhappy. I get angry quickly . . . I shall live long. . . . My daughter's husband has other loves and charges her with having lovers, a calumny. But he is watching her. Unless she have lovers, he can not divorce. Their life is a continual quarrel. Presenting imaginary situations to a soothsayer is not a bad way, I began to think, of observing social attitudes.

Such observation I had further opportunity to make at Agustina's as I listened to her divinations for some pilgrims to Mitla during the fiesta of San Pablo. The first client, from San José Pobresa, was a young woman carrying a baby. She was a widow and could not take care of her cows properly. Somebody was stealing from the herd. What should she do to check the robber? She was to offer two candles, one in the

[5] But from a "Spaniard," she said.

Calvario, one at the cross in the atrium, to Las Animas, the Souls; and in October during the fiesta of La Virgen de Jucila at Tlacolula, she was to visit Agustina again. Meanwhile Agustina herself would pray to Las Animas, pray that the robber turn to robbing the rich instead of poor widows. (In short, become another Robin Hood!)

Agustina's grains of yellow corn are already prepared. She pours them out from a tin box, about a hundred dry grains. She passes them from hand to hand, about eight times, praying over them, and in conclusion, cupping them in both hands, she breathes out hard on them, from the throat, moving her lips in a circuit. (Later, Eligio describes this breath rite as saying, "*En nombre del Padre, del Hijo, y del Espíritu Santo,*" but, in imitating, Eligio blows from his lips. The expulsion from the throat is, I think, Indian.) Now with all the grains in her right hand she prays again and breathes out again. She moves her hand forward and back and throws the grains onto the *petate*. She studies the position of the grains, prays again, then tells what the corn is saying.

There follows the prayer made while holding the grains before casting. (Later she dictated the other prayers also, but they were unintelligible to Eligio as well as to me.)

> Eres maïs, eres sabiduría.
> Explica me hoy en este día
> Para poder explicar.
> Eres planeta de flor,
> Eres la rueda de la fortuna.
> A llegar en la mata
> Les convenca al instante.

Ten centavos is the charge for each particular divination, but dictation of the prayers cost me five pesos. And the prayer said by Agustina when she "sucks," a prayer learned from her uncle, the priest, would have cost much more had it seemed worth it to me. Her prayers appear to be as precious and costly to Agustina as prayers ever appear to be to an Indian.

After the widow leaves us, in comes a family of father and mother with her baby and a boy of thirteen, also from San José. What sickness afflicts his wife? asks the man who is spokesman throughout. All these San José visitors, by the way, talk to Agustina in Spanish, which is a more intelligible medium for them than their diverse Zapoteca dialects. The woman has pains in her chest and in her back, low down. For this, after her initial ritual and casting, Agustina prescribes rubbing the back with the warm urine of the baby, butter and lime water; and rubbing the chest with an infusion of *oja de grilla*. Also Miguel is to pay two pesos for a mass (*pagar una misa de dos pesos*). And Juana is advised to keep to herself, away from trouble-making friends—"*Las amigas van a platicarlo a su contrario y de alli empieza el pleto.*"

Miguel's elder son and daughter-in-law are living with him; the daughter-in-law is restless and wants to leave her husband. What is to be done? The corn, recast, advises that the son, whose name Agustina asks for, and his wife set up an independent household; otherwise within two or three months the woman would cease to respect her father-in-law. In time the son will become rich. For help in smoothing out the situation, Miguel is to take a candle to the church for the Corazon de María, and another for Jesus Nazarino.

After her last cast Agustina announces that a death threatens in the family. "*No de casa?*" asks Miguel very anxiously.

"*No, pero son familia.*"

Against this danger Miguel is to pay for six *responsos*, three for *Las Animas Solas*, three for *Las Animas Común*, a distinction between the souls which seemed quite familiar to him as well as to Agustina, but which nobody I subse-

quently questioned was clear about. *Animas Solas,* yes, that was a common term, perhaps it referred to those who died without any family to care for them after death; but *Animas Común,* nobody used that expression.

Miguel seems well satisfied, he repeats all he has to do and takes off his money belt to find the fee, fifty centavos. Agustina gets out some oranges, gives me one and a piece to the baby. Miguel offers us cigarettes. Later when I visit the church I find Miguel and his family on their knees before the altar rail. In front on the ground burn the candles he bought from Agustina, and six times to the *cura* Miguel pays for the prayers and asperging which constitute a *responso* for the dead. Did the *cura* know, I wondered, that he was praying to preclude a death or did *he* know the difference between *Las Animas Solas* and *Las Animas Común?* And I wondered if other *curanderos* in other parts of Mexico were such faithful pillars of the church as Agustina. If so, Catholicism in Mexico had at least one base that anticlerical legislation could not shake.

SCIENCE SERVICE RADIO TALKS

PRESENTED OVER THE COLUMBIA BROADCASTING SYSTEM

ADVENTURES WITH ELECTRICITY IN A PARTIAL VACUUM

By Dr. KARL T. COMPTON

PRESIDENT OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

It is no exaggeration to say that the most exciting developments in physical science during the last generation are those which have been associated with a study of what happens when an attempt is made to force an electric current through a partial vacuum. Not only have these experiments led to the discovery of the electron and to the accurate weighing of individual atoms and molecules, but they have also led to much information regarding the architecture of these inconceivably tiny yet incomparably active bits of matter. They have also led, on the practical side, to the discovery of phenomena and the invention of devices which have opened up entirely new avenues of activity and achievement. Among such discoveries may be mentioned X-rays, which have revolutionized diagnostic medicine, which have revealed those differences in molecular arrangement that determine the suitability or unsuitability of a metal for a great number of important industrial purposes, which detect the flaws in armor plate or welded joints and which in general enable us to see many things otherwise invisible. These experiments have also produced such familiar objects as the illuminated gas signs in the variety of brilliant colors which are now the striking feature at night of every city, the little rectifiers which charge your automobile batteries, much of the apparatus which operates your theater lights or your automatic electric machinery, but above all in their influence on the life and thought of the present generation, they have led to the radio tube, which has revolutionized the entire art of communication whether by wireless or by wire. It is particularly fitting therefore that in this talk on science to the radio audience I should describe some of the phenomena and experiments which have made the radio possible.

Nearly two centuries ago while experiments were being carried on with static electricity—of the kind which is produced when two dissimilar substances like wool and rubber or silk and glass are rubbed together—a peculiar difference in the behavior of positive and negative electricity was noted. I should here explain that the name positive electricity was quite arbitrarily chosen to designate that kind of electricity which is produced on glass when it is rubbed with silk, and that negative electricity is that other type of electricity which can neutralize positive electricity. Now, it was found that if a red-hot metal ball were given a charge of positive electricity it would retain this charge for a very long time, but that if it were given a charge of negative electricity the negative electricity would rapidly leak off through the air. If the ball were cold, on the other hand, there was no difference in the action of the two kinds of electricity on the ball, both being retained by the ball. Thus was discovered the peculiarity of negative electricity, that it can escape from a metal if the metal is hot.

Nothing more was learned about this

until more than a hundred years later when, in the 1880's, Thomas Edison discovered that electric currents could flow across the partial vacuum in his newly invented incandescent lamp, the direction of these currents indicating that negative electricity went out from the filament through the surrounding space to the glass walls or to any metal plate which might be placed within the bulb. This phenomenon was known as the Edison effect and was obviously closely related to that which had been discovered more than a century before.

Immediately following this discovery two German physicists named Elster and Geitel began a very extensive series of tests in an attempt to discover the cause and nature of these currents of negative electricity proceeding from hot metals. For this study there was designed an apparatus very crudely similar to a modern radio tube in that it contained a filament which could be heated by passing an electric current through it, and another electrode—and the intervening space within the glass tube could be filled with any desired kind of gas at any desired pressure. In these experiments it was found again that negative electricity could pass through the surrounding gas from a hot filament to a neighboring electrode, that the size of this electric current depended very much on the temperature of the filament and also to some extent on its material and on the nature of the surrounding gas. Hundreds of observations were made and recorded, but these experiments led to absolutely no clue as to the cause of these currents or to any definite relationship between the size of the current and the temperature of the filament and other conditions.

Now let me digress for a little while to introduce to you that smallest yet most important part of the universe, the electron. Simultaneously with these experiments on hot filaments there had been going on a very intensive study of those peculiar luminous and electric effects which occur when electricity at high voltage passes through a long partially evacuated tube. The contents of the tube are luminous with various spectral colors characteristic of the type of gas in the tube. Starting with atmospheric pressure and gradually pumping the gas out from one of these long tubes, meanwhile maintaining a high voltage of perhaps some thousands of volts applied to its extremities, there is at first nothing to observe, since the air at high pressure is a good insulator. As the vacuum improves, however, there is first observed a long luminous streamer which gradually expands until it fills the whole tube with a uniform soft glow. As the vacuum improves with still further pumping, this luminosity separates into well-defined regions, sometimes of different colors and separated by regions of darkness. As more and more gas is pumped out these luminous striations move to the positive end of the tube and disappear, while their place is taken by a different type of luminosity which creeps up after them from the negative end and finally fills the whole tube. At about this stage, moreover, the glass walls begin to glow with a greenish fluorescent light, and it is at this point that X-rays begin to emanate from the tube. Finally, if the gas is pumped out to the extent possible with our modern high vacuum pump, a stage is reached at which the current through the tube and the luminosity cease entirely. In this striking series of phenomena are to be found the essential occurrences of electric arcs, sparks, lightning, aurora borealis and all other phenomena of electric discharge through gases.

It was while searching for the cause of these electrical and luminous phenomena that Wilhelm Konrad Roentgen discovered X-rays and a brilliant group

of physicists headed by Sir J. J. Thomson discovered electrons, whose rapid motion at the high voltages and whose vigorous bombardment of molecules in their paths were the cause both of the electrical conductivity of the gas and of the luminous radiation emitted by it. These electrons were discovered almost exactly thirty years ago, and from that day to this, scientific discoveries have followed at a pace never before even dreamed of in the history of mankind.

Within a year after the discovery of electrons it had been proved that the negative currents of electricity which escape from a hot filament are constituted simply of a stream of electrons. Another brilliant young English physicist named Richardson, as his doctor's thesis put forward the theory that these electrons were simply evaporated out of the metals by essentially the same processes which are involved in the evaporation of a substance like water. He worked out this theory quantitatively to give the relation that would be expected between the rate at which this evaporation occurred and the temperature of the metal, or in other words, the relation between the electric current and the temperature, and then he carried on a series of notable experiments which proved the accuracy of his theory in a remarkable fashion. His theory is found to be accurate from the smallest to the largest currents which have been measured coming from hot filaments, a range in which the largest currents are at least a thousand, million, million fold greater than the smallest.

As I have heard the story of the first invention underlying the radio tube, it is this. Richardson was reporting the results of his theory and experiments before one of the British scientific societies. In the audience was a well-known electrical engineer named Fleming. During the address Fleming conceived the idea of using this phenomenon to produce an electric valve, that is, a device which would allow electricity to flow in one direction through the tube but which would prevent any such flow in the opposite direction. This is possible, you see, because negative electricity comes out of a hot filament but positive electricity does not, consequently electricity can flow in only one direction from the filament. Fleming sketched his idea on the back of an envelope and after the lecture propounded it to Richardson, who agreed that the idea was feasible. On the basis of their discussion Fleming took out his patent on the so-called Fleming valve, a valve which, when connected in the antenna circuit of a receiving wireless set, would convert the alternating current of the radio wave into a direct current which could be detected by suitable instruments.

About a year later than this, that is, approximately twenty-five years ago, Fleming discovered that this valve could be much more sensitive as a detector for wireless waves if a sufficient voltage were applied between the filament and the neighboring anode to produce a slight ionization of the small amount of residual gas in the tube—in other words, to speed up the electrons coming from the filament sufficiently to break up gas molecules with which they happened to collide. This was the origin of the so-called "soft" detector tube of the radio art up to a few years ago.

From that time on improvements and inventions have been numerous and rapid. A great step forward was taken when De Forest introduced the grid between the filament and anode of the Fleming valve and showed that currents could be amplified and controlled according to the incoming signal from the antenna by the voltage impressed from the antenna on this grid. These audion tubes, so-called, while sensitive, were somewhat erratic, and principally

through the researches of Langmuir a new tube came into being which had all the appearances of the old one but differed from it in having the gas pumped out of it by such improved methods that the amount which inevitably remained was too small to affect the operation of the tube, so that instead of depending on or being affected by gas ionization accompanying the flow of electrons from the filament, the modern tube is made as free from this as possible. Under these conditions the detector action of the tube is due to another phenomenon quite different from gas ionization. Finally, to complete the major aspects of the story, I must mention the additional great improvements which have come through a discovery of the most suitable materials for use as filaments, materials which will give a steady flow of electrons and which will give a sufficiently large flow at the lowest possible temperature. The present tubes almost universally contain filaments of tungsten coated in an interesting way with a layer of the rare radioactive element, thorium, only one atom deep over the surface—again, a discovery due to Langmuir.

In this brief talk I have dwelt principally upon the development of the radio tube, but have mentioned in passing the X-ray tube, the luminous gas tube, arcs, sparks, etc. Each of these subjects has behind it a story of absorbing scientific interest; each is at the present time engaging the attention of a large number of scientists and engineers in university and in industrial research laboratories; and each is playing now and is destined to play in the future an important rôle in the electrical industry.

Our present age is often designated as the electrical age. There are many who see indications that the electrical age in the next generation may develop into one which is to a large extent dependent on devices which have come from a study of the discharge of electricity through gases.

It may be interesting to amplify just a bit this last statement. In the early days of electrical engineering, that is, about fifty years ago, electric power was generated, distributed and used in the form of direct current, that is, the electric current always flowed through the wire in the same definite direction. Soon, however, it became evident that it was advantageous to use very high voltages for transmitting electric power over great distances because the loss of power in the wires is less at high voltage than at low voltage. By means of a transformer, electric current can be changed from low voltage to high voltage or *vice versa.* However, it is only alternating currents which change their direction many times a second, which can thus be modified in voltage by means of a transformer, and for this reason the present-day electrical industry is entirely an alternating current industry, except for a few particular purposes for which direct current is essential.

Within the past few years, however, an instrument based on electrical discharge through a rarefied gas in a bulb has been developed by Dr. Hull, of Schenectady, which makes it possible to change direct currents from high to low voltage or *vice versa,* and if these instruments, known as thyratrons, prove as practical as now seems probable, the next dozen years may see a return of the direct current in power transmission systems. Such a development would simplify certain problems of insulation and mark a very decided advance in the economy and efficiency with which large amounts of electric power may be handled.

These few illustrations which I have described will, I hope, prove to your satisfaction that adventures with electricity in a partial vacuum have been both interesting and of practical value.

RADIO AND THE OUTER ATMOSPHERE

By Dr. EDWARD O. HULBURT

SUPERINTENDENT OF THE HEAT AND LIGHT DIVISION, U. S. NAVAL RESEARCH LABORATORY, WASHINGTON, D. C.

I WISH to describe some recent advances in the knowledge of the outer atmosphere of the earth which have resulted from the wide-spread development of radio telegraphy. In 1901 Marconi succeeded for the first time in sending wireless signals across the Atlantic Ocean. Lord Rayleigh, the renowned English physicist, immediately asked how the wireless waves traveled such long distances, for they could neither go through the earth nor without help bend very much around the curvature of the earth. In answer Professor Kennelly, of Harvard University, and Professor Heaviside, in England, suggested that the air in the high atmosphere might be sufficiently electrified to reflect the wireless waves. Thus the waves would be guided around the bulge of the earth traveling between the surface of the land or sea and a more or less parallel reflecting layer overhead. During the next twenty years the suggestion remained hardly more than a suggestion in spite of the fact that the use of radio waves expanded at a very rapid rate. Little progress to a better understanding of the behavior of the waves took place. Some new facts were needed. These came in the years around 1920 to 1924 with the discoveries of the remarkable properties of the short wireless waves below 50 meters in length. It was found that the short waves could be transmitted long distances, thousands of miles or even twice around the earth, with relatively little power. Curiously enough at near distances they could not be used. After leaving the transmitter they went up into the air, skipping over the nearby region, and came down to the earth again several hundred miles away. The "skip distance" was regarded as almost the first direct experimental proof of a reflecting region overhead The Kennelly-Heaviside layer changed from a theory to a reality.

The behavior of the short wireless waves was investigated by the far-flung organization of the United States Navy in an extensive program of measurements carried out with the cooperation of the radio amateurs all over the world. The skip distances were found to be greater as the wave-length was made shorter. They were first measured carefully for four different wave-lengths—16, 21, 32 and 40 meters—giving four points on a curve From four points on a curve a mathematical physicist can construct a new theory of the universe. Not quite this was done in this case, but from the four points it was possible to calculate the maximum density of electrification in the reflecting layer and the height of the layer above the earth. The height came out about 100 miles above sea-level, and in the densest part of the layer there were about 300,000 electrons per cubic centimeter and a large number of ions. An electron, as you all know, is the smallest unit ot negative electricity, and an ion is a molecule, or an atom, which has become charged with either positive or negative electricity. The charged particles are spoken of as the "ionization," and an ionized gas is one which contains a number of such charged particles. In the meantime other experimenters were determining the height of the layer and the electron density by measuring the time for pulses of radio signals to travel up to the layer and back to the earth

again, and by measuring the angle of the downcoming waves. The values obtained by these methods agreed with those of the skip distances. Thus it is now an established fact that all radio signals, broadcast programs, etc., which are received at distances beyond 50 miles from the transmitter have traveled 100 miles skyward and have bounded back to the earth again.

The skip distances and the ranges of the short waves were measured for night and day and for summer and winter conditions in various parts of the earth. The electron and ion density was found to be greatest at noon, to grow less all night and to be less in winter than in summer. The height was greater at night than in the day. The skip distances and the behavior of wireless waves in polar regions will be known as soon as the analysis of the large amount of valuable data brought back by the Byrd Expedition is completed. Their data include a record for almost every hour of the day for over a year on the Antarctic ice shelf. The radio phenomena of polar regions were of course not known when Byrd made his flight over the South Pole. The plans for the flight called for continuous radio contact between the plane and Little America. Because of the small power available, short waves had to be used. The Navy's skip distance and range tables for winter day conditions were studied carefully, and a 68-meter wave was chosen for the first 200 miles, which was shifted to a 45-meter wave at the 400-mile mark and then shifted to a 34-meter wave for the remaining 380 miles to the Pole. The schedule was executed, and it turned out that communication was excellent throughout the polar flight except for a weak period of 30 minutes or more after the shift to the 34-meter wave. The skip distance of this wave was slightly greater than had been estimated, and the plane had to fly some distance before it entered the zone of good reception.

After the fact had been established that ions and electrons existed in the high levels of the atmosphere from 50 to 150 miles one wondered what was the cause of the ionization. Since the ionization increased during the daytime and dwindled away at night it seemed pretty certain that the sunlight produced the ionization, especially so since ultra-violet light is known to ionize the gases of the atmosphere and since the sun emits ultra-violet light. Before the matter could be examined, however, one had to know what the atmosphere was like in these outer regions, regions above the blue sky—for most of the blueness comes from levels below 30 miles—regions visited only by meteors and wireless signals, regions where the air is very attenuated like the vacuum tube of the laboratory. The entire physics of the high atmosphere had to be worked out as well as possible, the wind velocities were estimated from the drift of the meteor trails, the day and night temperatures were calculated from the heating by the sun and the cooling by radiation at night, etc. Tables, theoretical of course, were prepared of the amounts of the various gases, nitrogen, oxygen, helium, etc., in the air to heights up to 200 miles. The daytime temperatures at levels above 70 miles came out to be about the boiling-point of water, and the night temperatures to be around 100 degrees below zero Fahrenheit. The ionization to be expected from the ultra-violet light of the sun was then calculated and was found to agree with that derived from the skip distances and other facts of radio. It was concluded that the Kennelly-Heaviside layer is caused by the solar ultra-violet radiations.

The ionization led to the explanation of a fact of the earth's magnetism which had long seemed very puzzling. The

analysis of the magnetic maps of the world by the usual gaussian harmonic method had shown that 98 per cent. of the earth's magnetism came from inside of the earth but that 2 per cent. was due to some unknown cause outside of the earth. It was seen from ordinary electromagnetic theory that the ions in the high atmosphere under the influence of the earth's gravitation and magnetic fields would drift, the positive ions going eastward and the negative ions westward. This constitutes an eastward electric current in the high atmosphere flowing continually around the earth, the current being mainly in the tropical latitudes and becoming weak at high latitudes. The current amounts to about three million amperes. It causes a magnetic field exactly equal to the unexplained 2 per cent. of external origin.

If the ultra-violet light of the sun is the cause of the ionization in the outer atmosphere one might expect the ionization to dwindle away almost completely in polar regions during the long Arctic winter night. But experiments with round-the-world radio signals and with other long distance signals, as well as more recently those of the Byrd Expedition, have shown that certain waves traverse polar regions during the winter night, indicating that ionization does exist there. One could point out, however, that in the outer fringe of the daylight atmosphere—at heights above 200 or 300 miles, regions verging into interplanetary space—molecules and atoms are continually sprayed away to great distances 30,000 miles or more from the earth. When these particles are ionized by the sunlight they do not fall vertically back to the earth, but are caught on the earth's magnetic field and fall along the lines of magnetic force into the polar regions. In this way the dark polar latitudes are kept supplied with ionization distilled in from the lower sunlit latitudes.

Thus far, although we have not said so, we have been speaking of the outer atmosphere during a time of calm. We shall now say a word about the storms which occur there. Magnetic storms have been observed systematically for the past 80 years. A magnetic storm is a small affair from some standpoints; for example, it is too small to trouble appreciably a mariner's compass. It causes, however, a tremendous wiggle in the curve which is traced continuously by the sensitive instruments of the magnetic observatory. And what perhaps is of more practical interest, the short-wave wireless signals were often found to be wiped out and the short-wave communication channels rendered inoperative during a magnetic storm. Magnetic storms differ from ordinary storms in that they occur at the same instant over the entire earth. They may last a few hours or several days; there may be only 10 or 20 storms during some years and as many as 50 or 100 during other years.

It has long been known that most magnetic storms are due to an outburst of some sort from the sun, but just what the eruption is like or where it is on the solar surface has not yet been discovered. The surface of the sun is like a burning prairie and is covered with countless flickering, blazing flames. Outbursts and upheavals of flaming gases occur continually, but no particular type of eruption has yet been identified with certainty as the cause of the terrestrial storm. Again it has been the behavior of the short radio waves which has given a clue to what happens on the earth during a magnetic storm, and what happens is a storm in the high atmosphere. To make a long story short the general idea of what takes place is as follows.

The solar outburst is a flare of ultraviolet light which usually blazes up to full intensity in a few minutes or an

hour, and dies away more or less irregularly in a day or so. The flare is probably difficult to see because most of its light, being in the far ultra-violet part of the spectrum, is absorbed in the high atmosphere and does not penetrate through to us. The effects of the absorbed radiation are interesting. The ionization in the upper atmosphere is increased and a million amperes or so are suddenly added to the three million amperes encircling the earth. The magnetic effects of the additional current are simultaneous over the earth and constitute the magnetic storm. The solar flare heats the high atmosphere in the daytime, causing it to expand outward. Calculation showed that the ionized layer should be lifted up about 50 miles during an average storm, and measurements with radio signals showed that this was so, increases in height of 30 to 70 miles being observed during magnetic storms.

The sudden heating of the daytime high atmosphere by the flare causes violent winds and turbulence in the ionized layers, so that the ionization is blown about like storm clouds or the waves of the sea. It becomes no longer a good reflector of the short wireless waves. During the night the disturbance dies down and increases again with the dawn if the solar flare is still in action. The short-wave channels of the United States Navy furnished evidence in favor of this view. To give one case: a magnetic storm began around noon, Eastern Standard Time, and continued for two days. The Atlantic seaboard and transatlantic short-wave circuits became inoperative the first day, recovered somewhat during the night and found trouble again with the dawn of the second day. Meanwhile the Pacific circuits, which were in the dark when the storm began, experienced no difficulties until the dawn and then showed weak signal intensity and violent fading which cleared up the following night.

The ultra-violet flare increases greatly the high flying ions which are sprayed away from the outer fringe of the high atmosphere The distillation of the ionization into the polar regions therefore is increased. This causes the aurora displays, which are known to occur during magnetic storms. But here I must stop—for the time allotted to this talk is limited—with just a mention that there is a connection between magnetic storms and the breaking up of comets and the variations in the zodiacal light.

INDUSTRIAL REVOLUTIONS

By WATSON DAVIS

MANAGING EDITOR, SCIENCE SERVICE, WASHINGTON, D. C.

It is not a governmental or political revolution that we are interested in this afternoon, but the quiet, gradual revolution, perhaps I should say evolution, of industries that has changed the physical environment in which you and I live.

Think back to the days of your own youth, the pre-radio days, the times when the airplane was a novelty, when telephones and automobiles were marks of distinction. It does not take a very long memory to remember when all silk was made by silkworms, lacquer was not made from cotton and every one expected all steels to rust.

Fate has not been kind to those industries that have been content to let well enough alone. Buggy factories are not paying extra dividends. The pace of the last few decades has been swift to those who have lived through them, but

it will seem even speedier to the historian with perspective.

Like it or not, the conditions under which we live to-day are vastly different from those under which our grandfathers were raised. Popular philosophers and alarmists at times set up cries against the cruelty of this machine age to its human subjects, to traditions, to ideas dear to conservatives of civilization that was. We may expect and respect them even if we do not agree with them.

There is little profit in complaining or praising, whichever is your inclination, without knowing whence and how this new age of ours came into being.

History as it used to be taught in the schoolbooks was largely a matter of kings and queens, generals and battles. It was a chronicle of the superficialities of politics and wars, flavored by the national partisanships of the country whose sons and daughters were reading the history books.

Napoleon set Europe aflame, but history may well give a more lasting place to the inventor or inventors of the match. In their influence upon the world, obscure inventors or scientists who worked in a garret have been more powerful than kings and presidents, although they may have suffered poverty and even ridicule in their own time.

From such beginnings the industrial revolution of to-day has been dreamed. The industrial revolutionists, as these pioneers of to-day's industrial commonplaces may be called, have served mankind without regard to the limitations of geographical boundaries and the passage of time itself.

Where would the automobile and airplane be to-day without the use of the cycle of Otto, German engineer? Where would the electrical industry be to-day without the scientific discoveries of Faraday, Englishman, and Joseph Henry, first secretary of the Smithsonian Institution? What would we do for tires and a multitude of other necessities without the vulcanization process of Goodyear? How could we do without the speedy communication of to-day made possible by the telegraph of Morse and the telephone of Bell? How uninviting our winter dinner tables would be without the success of the pioneers who put food in cans and kept it from spoiling.

These industrial revolutionists, quiet earnest men for the most part, often impractical and foolish in the eyes of their critical standpat contemporaries, are the true fathers of our industrial age. Their memory is in a hall of fame that needs no array of statues.

Do not for a moment conclude that the industrial revolution is over or even waning. It began when man first made fire; it has gained momentum speedily in the recent decades; it whirls about us, and it will rush on into future years.

We have among us to-day a few men whose ideas and genius, mixed often with a dash of luck, have influenced our civilization profoundly. Often their names are virtually unknown to the public, and the man in the street benefits from their labors without knowing whom to thank if he should feel so inclined.

With apologies to Mr. James W. Gerard, who recently picked a list of "rulers of America" which was conspicuous for its lack of government officials, let me assert that while the chairmen of boards of great corporations may rule our financial and even our political destinies, they do not mould our civilization.

Scientists and technologists, "industrial revolutionists," dead and living, are the individuals who are remaking our civilization. It is they whom bank presidents and industrial magnates must watch in order to safeguard their financial investments.

It is not easy to pick the industrial revolutionists among us to-day, but there are some who have seen their genius and hard work have a major effect on industry.

I nominate as to-day's industrial revolutionists:

Thomas A. Edison, who invented the incandescent electric light, who would be perpetually famous if that were his sole gift to mankind, but who pioneered in motion pictures and a multitude of other fields.

Orville Wright, joint inventor of the airplane, who was the first to fly in a heavier-than-air aircraft, an achievement that made possible the development of the air transportation of to-day.

Mme. Marie Curie, because with her husband she isolated radium, the radioactive element which has found commercial use as well as utilization in the treatment of cancer and other diseases.

Guglielmo Marconi, inventor of wireless telegraphy.

Dr. Lee De Forest, whose invention of the three-element electron tube laid the foundation of the great radio industry of to-day and who has been a pioneer in the development of talking motion pictures.

George Eastman, because he invented photographic film which made amateur photography easy and motion pictures possible.

Dr. Elihu Thomson, electrical engineer, whose researches on alternating current laid the foundation for the extensive transmission and use of electricity to-day and who is the father of electric welding, the silent builder of steel skyscrapers.

Dr. Fritz Haber and Carl Bosch, who, working for the great I. G. chemical combine of Germany, developed the production of synthetic nitrogen from the air by the direct synthetic ammonia process on such a scale and so economically that agriculture and industry are made independent of the natural nitrates of Chile.

Dr. Leo H. Baekeland, chemist, who invented bakelite, the synthetic plastic made from formaldehyde and carbolic acid, and who invented velox, photographic paper.

Georges Claude, French inventor and engineer, who devised the method of liquefying oxygen and other gases, invented the neon electric lamp and is now working on a method of obtaining power from the temperature differences in sea-water.

Frederick E. Ives, inventor of the half-tone process of illustration reproduction that is used thousands of times every day throughout the world in the printing of magazines, newspapers and books.

The group of Bell Telephone Research Laboratories engineers, headed by Dr. Herbert E. Ives, son of the half-tone inventor, who brought talking motion pictures by two processes to such commercial perfection that the motion picture industry went sound nearly overnight, who also perfected a process in television over wire and radio, and who has constantly improved the telephone.

Dr. W. D. Coolidge, General Electric physicist, who invented the X-ray tube in common use which bears his name, and the tungsten filament electric light.

Dr. Frederick Bergius, German chemist, who invented the hydrogenation of coal process by which oil can be made from coal and which is now being used in the refining of petroleum, and who is now developing a process for making edible carbohydrates from waste wood and other cellulose products.

Dr. Michael I. Pupin, who rose from immigrant to inventor, because of his invention of loading coils for telephone lines which makes possible conversations across continents.

Dr. F. G. Cottrell, who invented the

electrical precipitation of fine dust and other particles which is used to such advantage by smelters, cement plants and other industries that otherwise would pour out wastes that would pollute the air we breathe.

Dr. William M. Burton, whose process of cracking petroleum has made possible the production of enough gasoline to run the automobiles of the world.

Sir Charles Parsons, the British engineer who invented the steam turbine.

Sir Robert A. Hadfield, English metallurgist, who pioneered in the production of manganese and silicon alloy steels.

H. Brearley and Dr. W. H. Hatfield, English metallurgists, who pioneered in the production of stainless or rustless steels which now have wide commercial use.

Dr. Irving Langmuir, General Electric chemist, who invented the gas-filled electric lamp and atomic hydrogen welding.

The group of American chemists, including Professor H. P. Cady, of the University of Kansas, Dr. R. B. Moore and Dr. F. G. Cottrell, then of the U. S. Bureau of Mines, and their associates, who during the World War extracted from natural gas the sun-element, helium, hitherto known only as a rare inert elemental gas, and supplied it in such quantities that it now floats large airships.

C. Francis Jenkins, inventor, who pioneered in motion pictures and radiovision.

Chemists of the du Pont companies, who developed a new kind of paint, pyroxylin lacquer, and made it possible to paint automobiles with a cellulose compound.

Chemists of the I. G. Farbenindustrie A. G., Germany's dye trust, who produced new dyes, drugs and other synthetic organic chemicals.

Dr. Robert M. Yerkes and his psychological associates, who during the war devised the army mental tests which demonstrated to industry the utility of such tests.

Clifford W. Beers, "the mind that found itself," who, because of his experiences in an insane asylum, founded the mental hygiene movement which is rescuing thousands from mental illness.

Dr. S. M. Babcock, University of Wisconsin chemist, whose test for butter-fat content of milk put the dairy industry on a firm scientific basis.

Dr. L. O. Howard, veteran government entomologist, who long led America's war on the insect and who aroused the nation to the necessity of fighting insect invaders which menace health, crops and live stock.

Professor George H. Shull, botanist, who showed how to breed corn of higher yield that has meant millions of dollars to American farmers.

Dr. John Mohler, chief of the U. S. Department of Agriculture's bureau of animal industry, whose vigorous fight against foot-and-mouth disease of cattle has subdued that scourge and saved the live-stock industry untold loss.

Dr. Marion Dorset, Department of Agriculture biochemist, who developed methods of immunizing pigs against cholera and thus saved heavy losses in the industry of hog raising.

Dr. Theobald Smith, dean of American bacteriologists, whose work on Texas fever removed the menace of that disease of cattle, but, more important, proved that insects can carry disease.

Dr. Casimir Funk, who invented the term vitamin and called the attention of students of nutrition to early work on beriberi. This ushered in intensive research upon vitamins with resulting changes in food habits.

To this list there should also be added many pioneers in medicine whose researches have conquered many diseases, but time does not permit.

And there can not be included in this list, although perhaps there should be, the names of thousands of individuals who have aided in the birth of new ideas or perfected them so that they could do industry's work.

Great and important names in science, such as Einstein, Michelson, Millikan, Morgan, Rutherford and a host of others, are not in this list because their work, for the most part, has not yet been translated into industrial effects. That they are affecting the world's thought stream is undoubted; that even the most abstruse scientific discoveries will have industrial results in the future can not be doubted.

A decade more and it will be necessary to add to this list the names of some scientists and engineers who now are unknown even to their fellow workers. Absent from this list also are the names of those organizers and directors of research whose inspiration, planning and generalship have been as necessary to industrial revolutions as the achievements of the revolutionists themselves. Absent also, but with more reason, are financiers and capitalists who pay the modest salaries of the revolutionists or provide the funds to exploit their processes. They must derive their profits from the dividends that the industrial revolutionists make possible.

RACE PROBLEMS AS SEEN BY THE ANTHROPOLOGIST

By Dr. FAY-COOPER COLE

PROFESSOR OF ANTHROPOLOGY AT THE UNIVERSITY OF CHICAGO, AND CHAIRMAN OF THE DIVISION OF ANTHROPOLOGY AND PSYCHOLOGY, THE NATIONAL RESEARCH COUNCIL (1929–30)

I HAVE been asked to tell you in fifteen minutes some of the most important of racial problems as seen by the anthropologist. Perhaps I should begin by assuring you that an anthropologist is not a disease, but a student of mankind. It is his task to study man in all places and in all ages. He searches for man's early ancestors in the strata of the rocks and traces his development up to the modern races. In the same manner he traces culture from its simple beginnings, more than a half million years ago, up to our present civilization. By taking this long-time view and by studying all grades of culture it is possible to gain a prospective from which we can see our own society and our own race in its proper place.

But what do we mean by race? There is much confusion in the use of the term, and we find popular writers speaking of the French race, the Aryan race or the Jewish race. Now, of course, none of these are really races; France is a nationality; Aryan is a linguistic term and several races speak Aryan languages, while the Jewish people, once a nation, now form a religious caste.

In science when we use the term "race" we refer only to physical type. We mean a people who have in common certain physical characteristics which distinguish them from all other people. Have we such types? If you stand on the street corner of any large city and watch the crowd you quickly realize that there are marked differences in the people who are passing by. By the color of skin, character of the hair, projection of the face, thickness of lips and other characteristics you realize that one is a Negro, another is a Mongolian, a third is a Caucasian. Such broad classifications are easily made, and if you have had some training you will again divide these major divisions into

subgroups which we call races. For instance, the Caucasian division contains four races—the Nordic of northern Europe, the Alpine of central Europe, the Mediterranean of southern Europe and the Hindu of northern India. If time permitted we might learn that there are many characteristics on the living by which we can pick out the typical members of the races, and further study would reveal that equally clear marks of race are registered on the skeleton. We might also learn that there are differences in measurements which can be shown statistically. Race, then, is a definite thing, but race mixture is so common and individual variations within each group are so great that it is difficult to class a considerable proportion of any population.

The fact that there are differences in men raises many interesting questions and likewise many problems. One common assumption is that people who differ from ourselves are queer, are of a lower level and therefore inferior. This is a world-wide idea. Every tribe and people which still maintains its independence looks down upon its neighbors while using laudatory terms when referring to itself. Our modern civilized writers follow the same pattern, and we are told that the Nordic is the great race, responsible for all the great men of ancient and modern history. We are told that race is everything and that if we wish to preserve this fine stock for the future we must cut off immigration, not only from Asia, but from central and southern Europe. We are told by these writers that mongrel races partake only of the baser qualities of the inferior peoples. One writer basing his conclusions on experiments with guinea-pigs tells us that a hybrid race becomes infertile after the fifth generation and that we are committing racial suicide by allowing race mixture. We are also told that mixture of two widely divergent types, such as the small Lapps and the big-framed Swedes, is apt to result in monstrosities such as huge lungs and heart in a tiny body. To all such writers race mixture is a peril—dangerous to the perpetuation of the race, dangerous to the continuance of a well-balanced physical type, dangerous because the mixed races will ultimately swallow up the superior type and reduce all to mediocrity.

There are many more problems of a more technical nature, such as the actual inheritance of certain physical characters or clusters of traits, the susceptibility of certain races to disease, the ability of men of mixed racial stocks to stand the rigors of a northern climate or the effect of tropical sunlight. But time will only permit us to examine briefly the first group of problems.

If it is true that one race has furnished all the historic leaders and has made most of the contributions towards civilization, then that fact should be widely heralded and every effort should be made to keep that stock from intermixture. If it is true that hybrid groups become infertile after the fifth generation or that monsters may result from the mixture of diverse races, then intermarriage should be prohibited by law and the appearance of half-blood children should be severely penalized.

All such claims should be subjected to the closest scrutiny, since the welfare of our race and our nation is at stake. We have within our borders millions of people not only of different racial stocks but of the three major divisions of mankind. Does this constitute a peril? Do we have any facts on which we can base conclusions or which may aid us in planning and legislating for the future? First of all let me say that we have many known offspring of diverse races and that such mixtures do not produce monstrosities. Organs such as lungs

and heart apparently are not inherited as unit characters independent of the other portions of the body. Again, we have numberless cases of race mixture, even of most diverse strains, which after many generations show undiminished fertility. Among others, let me cite such mixtures as are found in the Philippines between the Malay and Pigmy black; between the Malay and Chinese, and between the mixed offspring of this union and the Spanish and other European peoples. Equally well-known mixtures are to be found in the Indies between the Dutch and the Malay. All through Malaysia and India are thousands of Eurasians who show no tendency toward decreased fertility. In America we find the same situation among the offspring of Indian-French and the Indian-Spanish unions. Apparently then we can dismiss the claim that race mixture is equivalent to race suicide.

The claim that racial superiority is established by the accomplishments of a people is fortunately subject to direct investigation. The advocate of Nordic supremacy points to the present dominance of northern Europe and America and says, "The proof of superiority is before you. The countries dominated by the Nordics lead in civilization. Dominance is proof of superiority." Let us test this claim for a moment.

In the year 2500 B. C. Egypt led the world. It was furthest advanced in all the arts and crafts of civilization. Had you asked the Pharaoh of that period if there was a superior race of people he doubtless would have said, "Certainly, and we are it." At about that time a Mediterranean people were developing a civilization on the island of Crete, but they did not rank with the Egyptians of the time. By the year 1500 B. C. they had progressed far beyond the civilization of the Nile and by every right they could have proclaimed themselves a superior people. This was just at the time the rude barbarians from the north, the tribal kings of the Odyssey and the Iliad, were pushing into Greece. Had you sought to compare these rude herdsmen with the Cretans of the Minoan period you would have been laughed to scorn. Yet they overcame the Cretans, borrowed liberally of their culture, intermarried with them, and by the year 500 B. C. this mixed population produced the golden days of Greece. Surely they were the dominant people of that age. By the beginning of our era Rome had wrested the leadership from Greece and was attempting to subdue the rude barbarians of the north. If you wish to learn what the Romans thought of our ancestors in central and northern Europe and in the British Isles, just read again your Cicero and your Caesar. There was no doubt in the mind of the Roman but that he belonged to the great race. But the northern barbarians showed themselves capable of learning, and ere long they overthrew Roman power and are now the leaders of civilization.

Apparently then the fact that a nation or race is dominant at any particular time is no assurance that it will retain the leadership. Archeology and history teach us that civilization has shifted from one region and people to another, and that the less advanced people of one period become the leaders in another age.

The presence of many races and peoples in America does raise real problems, problems requiring the greatest statesmanship and tolerance. Race mixture will continue, we will become more of a hybrid people than we are at present; but if we scan the history of the past or consider the known facts of race and race mixture we need have no fear for America of the future.

THE PROGRESS OF SCIENCE

THE CLEVELAND MEETING OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE AND ASSOCIATED SCIENTIFIC SOCIETIES

THE eighty-seventh meeting of the American Association for the Advancement of Science will be held in Cleveland during the convocation week beginning December 29, 1930. This will be the fourth time the association has met in Cleveland, the other meetings having occurred in 1853, 1888 and 1912–13. Besides the fifteen sections of the association about forty independent societies will hold scientific sessions.

The societies which deal with the social and economic sciences have preferred to hold their sessions in the hotels of the down-town district, but the remaining ones, concerned chiefly with the natural and exact sciences, will have their sessions mainly in twenty buildings of Western Reserve University and Case School of Applied Science, both situated at University Circle about four miles from the down-town area.

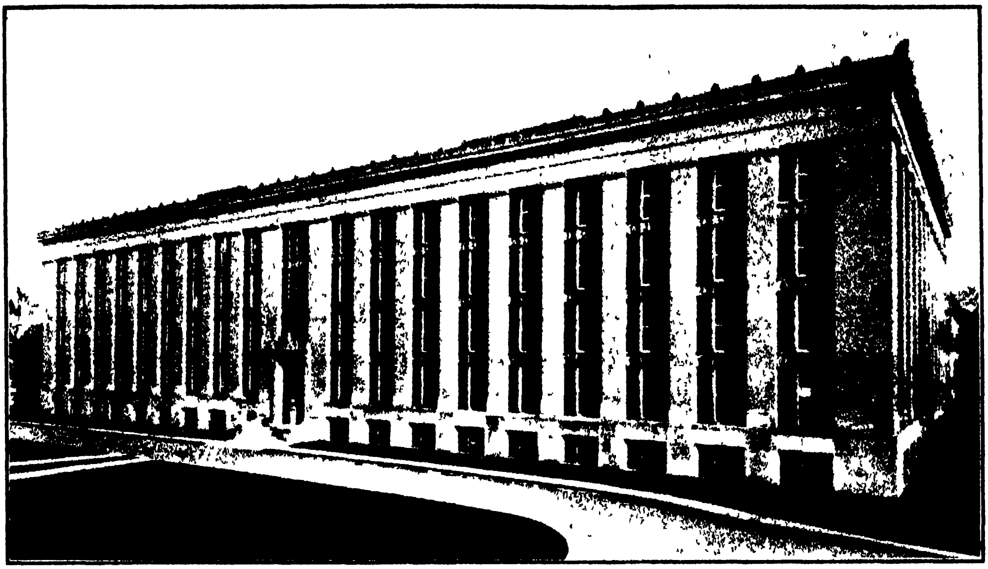
The registration headquarters for the University Circle group will be located in the gymnasium of Western Reserve University. In the center of the large floor will be located such things as the registration desks, post-office, telegraph and telephone equipment, information desk and bureau for validation of railroad tickets, while in booths around the walls will be placed the general scientific and commercial exhibits dealing with recent advances in pure and applied science. The gymnasium thus provides a place where members and visitors may find a common meeting ground. The news service department for the convention will be located in a wing of the same building.

The opening session will be held down-town in the Music Hall of the Public Auditorium. After brief addresses of welcome the president-elect, Dr. Thomas Hunt Morgan, director of the Kerckhoff Laboratories of the Biological Sciences

THE GYMNASIUM BUILDING OF WESTERN RESERVE UNIVERSITY
REGISTRATION HEADQUARTERS AND EXHIBIT HALL.

DR. THOMAS HUNT MORGAN

PRESIDENT OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.



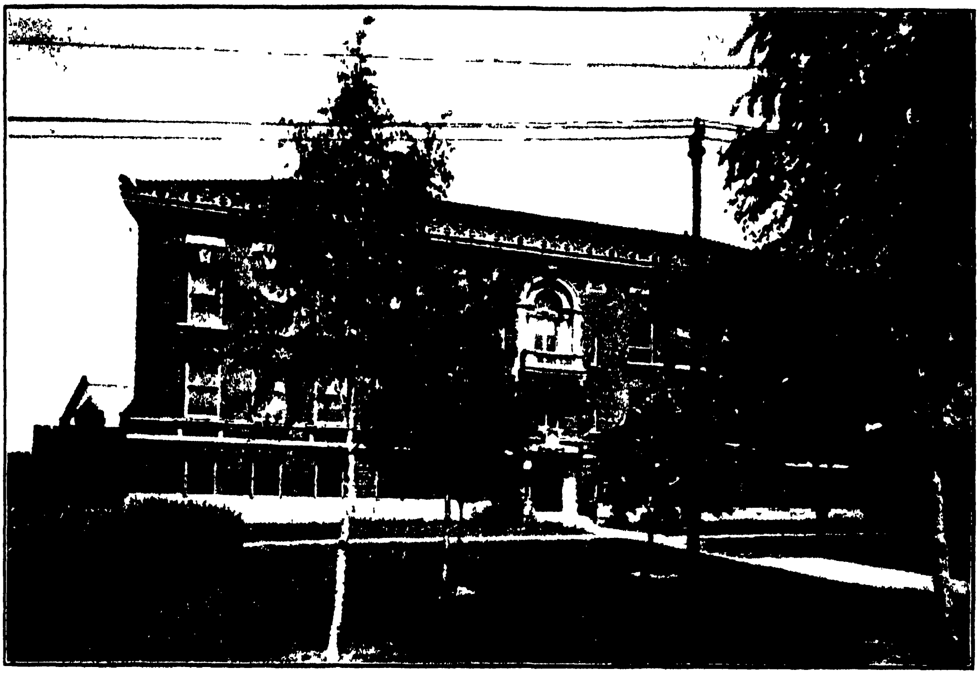
THE SCHOOL OF MEDICINE OF WESTERN RESERVE UNIVERSITY

of the California Institute of Technology and president of the National Academy of Sciences, will introduce the retiring president, Dr. Robert Andrews Millikan, head of the California Institute of Technology and director of the Norman Bridge Laboratory of Physics, the subject of whose address, the main lecture of the meeting, will be "Atomic Synthesis and Atomic Disintegration" These exercises will be followed by the usual reception, which will be held in the same building.

Meeting places for about two hundred sessions of the various sections and societies have been assigned, where scientific and technical papers will be read and discussed. But, besides these papers, the program includes the usual laboratory demonstrations, symposia and general addresses, a number of which will be of interest to those who are not specialists. Among the latter may be mentioned the Sigma Xi lecture on "The Science of Photography," to be given on Tuesday evening in the John Hay High School Auditorium by Dr C. E K. Mees, of the Eastman Kodak Company. Many will desire to hear the annual Josiah Willard Gibbs lecture, arranged by the American Mathematical Society, which is to be given on Tuesday afternoon in the auditorium of the John Hay High School by Dr. Edwin B. Wilson, of Harvard University. Dr Wilson's subject, "Reminiscences of Josiah Willard Gibbs," is especially appropriate when we recall that he was a student and colleague of the eminent scientist. Immediately following Dr. Wilson's address the Sigma Xi dinner will be held at the Cleveland Club, which is directly across the street from the John Hay High School. On Wednesday afternoon Professor Harlow Shapley, director of the Harvard College Observatory, will speak on "Galactic Observations." This address by a most renowned authority will be given in the Allen Memorial Medical Library. Another general session lecture will be one by Dr. Aleš Hrdlička on the subject, "Animal-like Manifestations in the Human Child"

It is to be regretted that congenial scientific spirits find so little time for social intercourse, nevertheless, the local committee has planned the usual luncheons, teas, dinners and smokers. Those

DR. ROBERT ANDREWS MILLIKAN
Retiring President of the American Association for the Advancement of Science.



THE PHYSICAL LABORATORY OF THE CASE SCHOOL OF APPLIED SCIENCE

registering will have entrée to the Cleveland Club and to the Art Museum There will be daily excursions to Nela Park, a unique institution of the General Electric Company. Tickets for the various play-houses and symphony concerts will be available at the registration headquarters in the gymnasium.

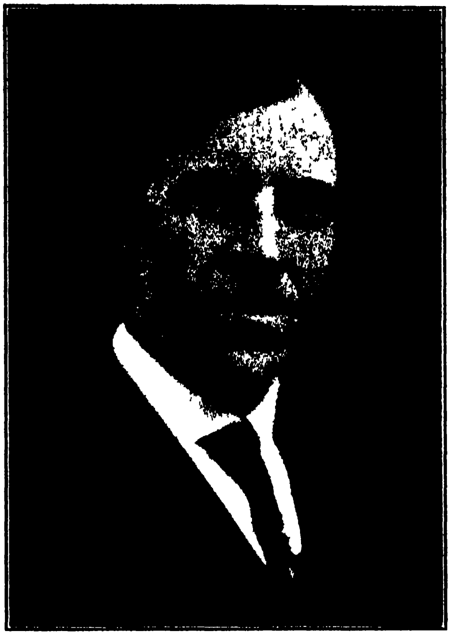
The local arrangements for the meeting at University Circle are in the hands of an executive committee, of which Dr. Harry W. Mountcastle, professor of physics and astronomy in Western Reserve University, is the active chairman Dr. Robert E. Vinson, president of Western Reserve University, is the honorary chairman, while the Case School of Applied Science is represented by its president, Dr. William E. Wickenden, as honorary vice-chairman. The officers of the association, the Cleveland local committee, with its various special committees, and the Convention Board of the Cleveland Chamber of Commerce are all cooperating in the endeavor to make this one of the most enjoyable convocations which the association has held.

The council of the American Association will hold a session each day during convocation week. The executive committee also holds daily meetings.

The Secretaries' Conference, a special committee of the American Association, plans to hold its annual dinner and session at Cleveland. The secretary of this conference is Dr. Harley J. Van Cleave, secretary of the American Microscopical Society, who has charge of the program The chairman is Dr. Philip Fox, secretary of Section D. The conference consists of the secretaries of the association sections, the secretaries of the associated societies and the members of the executive committee of the association.

The Academy Conference of the American Association is planning to hold its Cleveland session at the close of the first council session. This conference consists of the council representatives of the affiliated academies of sci-

DR. G. A. BLISS
PROFESSOR OF MATHEMATICS, UNIVERSITY OF CHICAGO, CHAIRMAN OF THE SECTION OF MATHEMATICS.



DR. F. K. RICHTMYER
PROFESSOR OF PHYSICS, CORNELL UNIVERSITY CHAIRMAN OF THE SECTION OF PHYSICS.

DR. JAMES F. NORRIS
PROFESSOR OF ORGANIC CHEMISTRY, MASSACHUSETTS INSTITUTE OF TECHNOLOGY, CHAIRMAN OF THE SECTION OF CHEMISTRY.

DR. D. W. MOREHOUSE
PROFESSOR OF ASTRONOMY AND PRESIDENT OF DRAKE UNIVERSITY; CHAIRMAN OF THE SECTION OF ASTRONOMY.

DR. EDSON S. BASTIN
PROFESSOR OF ECONOMIC GEOLOGY, UNIVERSITY OF CHICAGO, CHAIRMAN OF THE SECTION OF GEOLOGY AND GEOGRAPHY.

DR WM A. RILEY
PROFESSOR OF ZOOLOGY, UNIVERSITY OF MINNESOTA; CHAIRMAN OF THE SECTION OF ZOOLOGICAL SCIENCES.

DR. E. J. KRAUS
PROFESSOR OF BOTANY, UNIVERSITY OF CHICAGO; CHAIRMAN OF THE SECTION OF BOTANICAL SCIENCES.

DR. CARL E. GUTHE
DIRECTOR OF THE MUSEUM OF ANTHROPOLOGY, UNIVERSITY OF MICHIGAN; CHAIRMAN OF THE SECTION OF ANTHROPOLOGY.

ence and three representatives of the association. The secretary of the conference this year is Dr. Chancey Juday, of the Wisconsin Academy, who has charge of the program. The chairman is Dr. D. W. Morehouse, of the Iowa Academy.

The eighth annual award of the American Association prize, of one thousand dollars, will be made to the author of a paper presented at the Cleveland meeting. Through the generosity of an anonymous member seven of these prizes have thus far been awarded The prize is awarded each year to the author of a noteworthy paper presented at the annual meeting. It is not necessary that the author be a member of the association. All papers appearing in the General Program are automatically eligible, excepting invited papers and presidential and vice-presidential addresses. In making the award no attempt will be made to select the "best" paper presented, for useful comparisons are not possible in different fields of science; the intention is simply that the prize shall be awarded to the author of some notable contribution presented at Cleveland Previously published work may be considered when pertinent. The donor of the prize desires to aid younger authors by this means rather than to honor older men. The prize is not to be awarded in the same field of science for two consecutive years.

DR. FRANK B. JEWETT
PRESIDENT OF THE BELL TELEPHONE LABORATORIES: CHAIRMAN OF THE SECTION OF ENGINEERING.

DR. EDWIN G. BORING
PROFESSOR OF PSYCHOLOGY, HARVARD UNIVERSITY; CHAIRMAN OF THE SECTION OF PSYCHOLOGY.

A list of the names of those to whom the association prize has been awarded is shown below, together with the topics dealt with in the winning papers.

(1) The Cincinnati award, January, 1924. L. E. Dickson, for contributions to the theory of numbers.
(2) The Washington award, January, 1925. Divided equally between Dr. Edwin P. Hubble, for contributions on spiral nebulae, and Dr. L R. Cleveland, for contributions on the physiology of termites and their intestinal protozoa.
(3) The Kansas City award, January, 1926.

Dr Dayton C. Miller, for contributions on the ether drift experiment.

(4) The Philadelphia award, January, 1927 Dr. George D. Birkhoff, for mathematical criticism of some physical theories

(5) The Nashville award, January, 1928 H. J. Muller, for contributions on the influence of X-rays on genes and chromosomes.

(6) The New York award, January, 1929 Oliver Kamm, for contributions on the hormones of the pituitary gland.

(7) The Des Moines award, January, 1930. A. J Dempster, for contributions on the reflection of protons from a calcite crystal

All members of the association are asked to secure new members or to send to the permanent secretary's office in Washington names and addresses of persons who might be interested in joining the association. Copies of a booklet on "The Organization and Work of the American Association," as well as membership application cards and sample copies of the journals, may be secured at any time from the permanent secretary office. Membership in the association includes a subscription to the weekly journal *Science* or the SCIENTIFIC MONTHLY, for the calendar year beginning at the close of the annual meeting. The journal alone is worth more than the annual membership dues. Annual members of the association may have both *Science* and the SCIENTIFIC MONTHLY by paying $3 00 in addition to the annual dues ($8 00 in all), if the additional payment accompanies the remittance of annual dues Annual members of the association may also subscribe for the *Science News-Letter* at the specially reduced price of $3 00 per year, if the additional remittances accompany their payment of dues in each case. Life members may receive one or both of the extra journals by paying $3.00 for each subscription.

New members of the association regularly pay an entrance fee of $5.00, but this year that fee is remitted to members

DEAN WALTER C. COFFEY
DIRECTOR OF THE DEPARTMENT OF AGRICULTURE, UNIVERSITY OF MINNESOTA; CHAIRMAN OF THE SECTION OF AGRICULTURE.

DR. LEONARD V. KOOS
PROFESSOR OF EDUCATION, UNIVERSITY OF CHICAGO; CHAIRMAN OF THE SECTION OF EDUCATION.

of any associated organizations, including the affiliated state academies. Those who take advantage of this privilege and join at the Cleveland meeting without paying the entrance fee should fill in the blanks on a blue membership application card and present card and dues for 1930-31 ($5.00) when they register. All who attend the Cleveland meeting are asked to join the American Association when they register, unless they are already enrolled.

Those who are not members of the American Association and who do not wish to join at this time are invited to become associates for this meeting. The associate fee is $5.00. Associates have all the privileges of the meeting, except voting, and they will receive the general reports of the meeting when these are published about February 1. They are to register without paying any registration fee. Associate fees will be used to help defray the costs of the meeting.

DR. LEONARD P. AYRES
VICE-PRESIDENT OF THE CLEVELAND TRUST COMPANY; CHAIRMAN OF THE SECTION OF SOCIAL AND ECONOMIC SCIENCES.

DR. LOUIS B. WILSON
PROFESSOR OF PATHOLOGY AND DIRECTOR OF THE MAYO FOUNDATION; CHAIRMAN OF THE SECTION OF MEDICAL SCIENCES.

Visitors from outside of the United States and Canada who are not members of the association may be invited to the meeting as foreign associates. Members of the association may recommend to the permanent secretary persons who should receive official invitations, giving reasons. Eligibility to this honor is about the same as eligibility to fellowship in the association.

Much information concerning such things as hotel headquarters, transportation, meeting places and other details will be found in the preliminary program published in the issue of *Science* for November 28, 1930. The editor of this article is Dr. Burton E. Livingston, permanent secretary of the American Association for the Advancement of Science, who may be addressed at the Smithsonian Institution Building, Washington, D. C.

THE AWARD OF THE NOBEL PRIZE IN MEDICINE TO DR. KARL LANDSTEINER

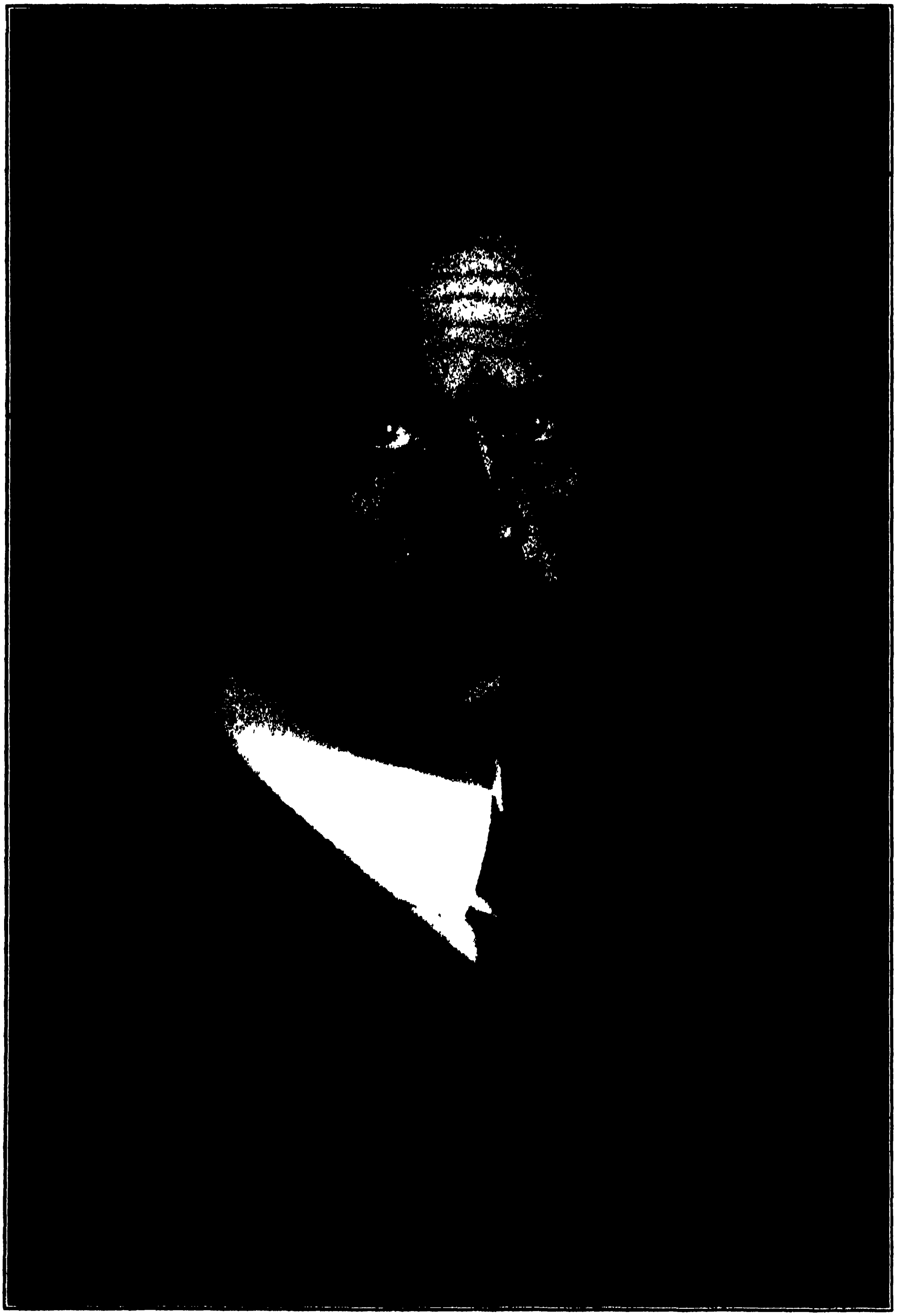
THE establishment of the Nobel Prize has had a value of far greater significance than the tangible rewards accruing to the recipients. It has created international public recognition of achievements which, in the ordinary preoccupations of men with material affairs, have often been completely neglected, or postponed until long after the death of the man or woman who has enriched human understanding In its scientific awards the commission which decides these matters has been extraordinarily well advised, and almost all its decisions have met with the enthusiastic approval of those most competent to know In consequence, the attention of a world concentrated on the temporary problems of political and economic affairs has been periodically diverted to the contemplation of the labors of the few who—undisturbed by the competitive turmoil, and often indifferent to material success—are making permanent contributions to the progress of intelligence which is civilization. And it is a good deal to admire even if one does not wholly understand The Nobel Prize Commission has almost invariably granted its awards for solid fundamental achievement which, without its wise judgments, would have been crowded out of public attention by more sensational things and which would, as often in the past, have penetrated to recognition only in the wake of later practical applications

In the ranks of the others so honored in his own field of study—Behring (1901), Koch (1905), Ehrlich and Metchnikoff (1908), Richet (1913) and Bordet (1919) Landsteiner takes his rightful place, long granted him individually by immunologists the world over, most of whom have been his admiring and grateful pupils.

The particular study for which the prize was bestowed was carried out as long ago as 1900 In his paper of 1901 the foundation for a new chapter in immunology was laid, and the tentative classification of human blood groups outlined in this publication was completed in the following year by Landsteiner's pupils, Descastello and Stürli, working under his direction. Since that time many excellent elaborations of this work have been published, but nothing was fundamentally changed or added In its consequences upon practical medicine and surgery, the influence of these studies has been considerable, but they have had a profound reaction as well upon genetics, anthropology and zoology.

Though important and fundamental, this work is only one of a series of achievements any one of which might have been cited as the immediate reason for the awarding of the prize Since 1894, Landsteiner has published about 115 papers, either alone or with various pupils The amount of work that he has inspired probably far exceeds in the number of titles the communications which stand in his name The distinguishing characteristics of Landsteiner's investigations are great originality of approach and an extraordinary mastery of the fundamental sciences. Without his broad knowledge of certain branches of chemistry and of physics, much of his most important work would have been impossible

Into his earlier period fall a considerable number of purely chemical investigations, such as a study on the behavior of diazo-benzol upon potassium permanganate, on chloric acid, on glycolaldehyde and on color reactions of proteins with sulphurous acid and the phenols By his earlier purely chemical interests he was induced to study the chemistry of antigen-antibody reactions, and occupied himself with chemical-pathological problems dealing with de-



DR. KARL LANDSTEINER

generation of the kidneys and the interrelationship of ferments and antiferments. During this earlier period, also, a number of studies in pathological morphology were published which may be regarded as exercises of general training and have no special significance in his development. In the first decade of the present century he published his important studies, with Finger, upon the susceptibility of monkeys to syphilis, as well as observations upon paroxysmal hemoglobinuria which established the mechanism responsible for this condition At this time he also began inquiries into the immunological significance of the lipoids. In 1909 came his successful transmission of poliomyelitis to monkeys, this being—with the work of Flexner and Lewis at the Rockefeller Institute- the fundamental observation upon the infectious nature of a group of diseases of the central nervous system now recognized to be due to filterable agents. His extraordinary versatility is evident in the fact that together with these purely biological studies he was already beginning his investigations into the behavior of antigen and antibody in the electrical field, upon the application of adsorption phenomena in antibody union and in physical analyses of specific precipitation and alexin fixation.

Landsteiner had thus, before 1914, in a series of investigations covering an extraordinarily wide field of endeavor, made fundamental contributions to the experimental study of syphilis and of poliomyelitis, had revealed the existence of human blood groups, and had basically modified our points of view regarding antigen-antibody reactions. In addition to this, in communications of less fundamental importance he had perfected methods of immunological technique and had occupied himself with purely bacteriological experimentation such as the cultivation of the virus of fowl plague, the technique of treponema demonstration, and the nature of the hemotoxins of the anthrax group of bacteria. Though many of his investigations up to that time were of the greatest importance and include the particular work for which the Nobel Prize was granted him, his most brilliant work was yet to come. None of the investigations so far mentioned will, in our estimation, possess so permanent and fundamental an influence upon the future development of immunology as his studies upon the chemical modifications of the antigens which were begun about 1913 and have been carried on in some twenty odd publications from that time to the present day.

Obermeyer and Pick had found, in 1906, that the specificity of proteins could be altered when the aromatic radicals were modified by the introduction of iodine, NO_2 and $N=N$ into the protein molecule. Such altered proteins produced antibodies which were specific for the alteration form of protein used in the immunization but not specific for the species from which the protein was derived From such observations grew a theory of specificity which for some time was generally accepted. Landsteiner, with a number of pupils, found that species specificity could be modified in many ways other than by alteration of the aromatic rings. He produced modified proteins by esterification with acid alcohol, by methylation and by a number of other methods which produced changes not affecting the aromatic radicles alone. He also modified protein by treatment with formaldehyde and by combining horse serum with derivatives obtained from various amino-compounds. By a series of investigations with the latter substances entirely too complex to be outlined here, he was able to bring strong evidence to indicate that the specificity of a protein antigen depends upon the chemical structure of a

relatively small part of the large protein molecule, and that when substitutions were made in the aromatic nuclei, the relative position, in the aromatic nucleus of the added group, of the significant radicle was as important as the substance introduced. None of this work could have been done without a broad knowledge and experience both in immunology and in the technique and reasoning of organic chemistry.

In carrying out this work, Landsteiner also found that if he produced antibodies by the immunization of an animal with a protein combined with a non-antigenic substance such as metanilic acid, the antibodies so produced, while specific for the compound protein that had incited them, would also react with the added group or substance, though the latter in itself was non-antigenic. The added group, in other words, was able to bind the specific antibody in vitro, thus rendering the antibody unable to react with the whole antigen, that is, with the protein into which the group had been introduced. This laid the foundation for our present knowledge of partial antigens, a branch of knowledge which has already become of the greatest importance in the study of bacterial antigens.

In its fundamental influence upon bacteriology, his latest work, published in 1928 and 1929 with Van der Scher, is perhaps the most significant of all. In these papers he reports upon experiments in which he prepared levo-, dextro- and meso-paraaminotartranilic acids and with these amino acids produced azo-proteins from horse serum. By immunization of rabbits with these azo-proteins he obtained immune sera which differentiated sharply the three antigens, which were identical in every other respect, but possessed stereoisomeric groups, thus indicating a specificity depending upon the asymmetric carbon atom. He suggests in this communication that since the tartaric acids by their chemical constitution belong to the same substances as sugar acids, these results may have bearing upon the specificity of bacteria containing carbohydrate partial antigens, and indeed this suggestion has already borne fruit for pneumococcus antigens in the hands of Goebel and Avery.

It has been often said that the qualities which make for great scientific achievements are very similar to those which lead to artistic production. At any rate, in most great biologists there has been an artistic streak which in Landsteiner—a typical Viennese—has taken the form of music. Indeed, though Landsteiner is fortunately now an American by adoption, his training and his personality and, we believe, the foundations of his great achievements are typically those of Vienna in her best days. We may claim him with pleasure as one of us now, but we can not justly claim any credit for his development, largely because almost all his great work was begun—and much of it finished long before he came to America. Like Loeb, Edmund B. Wilson and numerous other great men, his most characteristic personal trait is an almost childlike simplicity and gentleness. Perhaps one of the most descriptive facts that one can state in characterizing him is that the public knew practically nothing of him and few, outside of his close personal circle and those who had followed his work, knew that he was one of the few great living scientists until he was adjudged so by a jury of his professional colleagues through the Nobel Prize Commission.

HANS ZINSSER

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THE ATLAS MOUNTAINS OF MOROCCO

By Professor ANDREW C. LAWSON

UNIVERSITY OF CALIFORNIA

THE accompanying map (Fig. 1) shows that Morocco extends over eight degrees of longitude and six of latitude. Its Atlantic coast stretches southwest from the Strait of Gibraltar for over 800 km On the north it faces the Mediterranean for about 350 km. It adjoins Algeria on the east along a con-

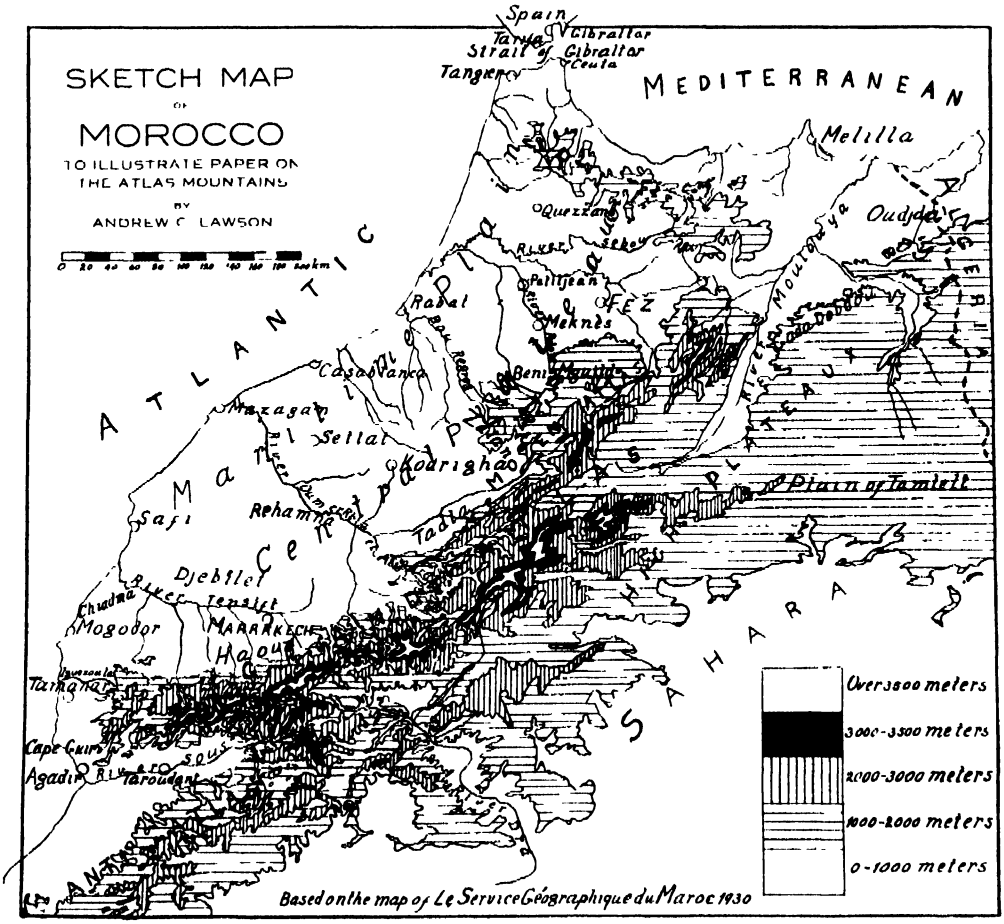


FIG. 1. MAP OF MOROCCO

SHOWING THE ATLAS BETWEEN THE CENTRAL PLATEAU AND THE HIGH PLATEAUX OF THE DESERT.

ventional boundary; but its limits on the south are indeterminate. Where Morocco ends and Sahara begins appears to be a matter of no political importance.

The Atlas Mountains, including in the system Beni Snassen, extend diagonally through Morocco from its southwest corner on the Atlantic to its northeast on the Mediterranean, the general trend being E.NE.; and they are flanked on both sides by plateaux and plains of diverse geomorphic character. The culminating peaks and ridges rise to altitudes of about 4,000 meters. In their descriptions of Morocco and on their maps of the country geographers have divided the Atlas into three ranges: (1) A central range known as the Grand or High Atlas; (2) the Moyen Atlas, lying to the northwest of the Grand Atlas in northern Morocco and separated from it only by the upper reaches of two opposed streams, the el Abid flowing southwest and the Moulouya flowing northeast; (3) the Anti Atlas, lying to the southeast of the south end of the Grand Atlas and separated from it only by the upper reaches of two opposed streams, the Sous and the Dra. The general trend of the Grand Atlas is slightly concave to the northwest, and the bearing of the range is a few degrees more nearly east-west than either the Moyen Atlas or the Anti Atlas.

The Rif Mountains in northern Morocco have a trend parallel to the concave Mediterranean coast, and appear on the map to be independent of the Atlas. They are an extension into Africa of the Bétic range of southern Spain. The structural ridges of the Bétic range curve around to a north-south trend in the vicinity of Gibraltar, and the formations which constitute them appear with the same trend on the south side of the strait, whence, curving easterly and then northeasterly in a mountain belt 250 km long, they pass out to sea in the vicinity of Melilla. The Rif is the Moroccan segment of a lobate range which is common to Europe and Africa. The Strait of Gibraltar and the submarine depression which determines it lie in the axis of the lobe. The north flank of the Rif is precipitate, while the south flank has a more gentle slope to the plateau which is traversed by the River Sebou, and which separates the Rif from the Moyen Atlas. This plateau, wide to the west and constricted to the east toward Taza, affords the only easy route for travel by land between western Morocco and Algeria. It has for that reason played a great rôle in the history of Morocco, and until recent years was politically and commercially the most important part of the country. The ancient capital cities of Fez and Meknès are situated on this plateau. To-day the most important commercial city is Casablanca on the Atlantic seaboard, and the chief political center is Rabat, also on the coast 87 km to the northeast, which is the seat of the French Residency.

The formations which enter into the make-up of the Atlas fall into two groups. The first of these comprises certain pre-Cambrian granites and schists of limited extent, a very large development of Cambrian quartzites, shales and limestones, and less extensive areas of Silurian, Devonian and Carboniferous strata. The rocks of this group were acutely deformed at the time of the Hercynian revolution and the resulting mountains, occupying a region very much more extensive than the present Atlas, were reduced to a peneplain. On this peneplain, and particularly in a geosyncline formed by the depression of a part of it, accumulated the formations of the second group. These comprise the continental deposits, fanglomerates, red beds, etc.,

of the Permo-Trias and the marine beds of the Jurassic, Cretaceous and Eocene. At the time of the Alpine Revolution this geosyncline collapsed, the rocks of both groups were more or less acutely folded, and a great mountain range took the place of the geosyncline. The thinner post-Carboniferous strata on the flanks of this Alpine uplift remained for the most part undisturbed, but there were areas of gentle folding, such as correspond to the foothills of a great range. The undisturbed strata and the flanking foothills stood much lower, horizon for horizon, than they do to-day. But, inasmuch as a thick prism of rock has been removed by erosion from these flanking regions since the Alpine Revolution, the surface of large parts of them may have been even higher than at present. Other parts were depressed in middle Tertiary time and, as in the region about Meknès and Fez, became embayments and straits of the Miocene sea.

The Atlas Mountains as we see them to-day are generally regarded as the product of the Alpine Revolution at the end of the Eocene. It is the purpose of this paper to show that while the structure of the Atlas, as displayed in its Mesozoic and early Tertiary formations, is properly referable to the Alpine earth movement, the region surrounding the range was reduced to a peneplain, and the range itself to residual hills, before the end of the Tertiary; and its present altitude and sculpture are due to the uplift of the region, including the hill range, by arching, and the upthrust of the latter by faulting.

From a geomorphic point of view the Atlas has the characteristics of a very youthful range. The canyons are narrow and V-shaped; and the crests are sharp ridges and peaks formed by the intersection of the canyon slopes. The streams have a torrential habit and flow in trenches far above the base-level of erosion. The general features are comparable to those of the southern half of the Sierra Nevada of California, the uplift and sculpture of which date from the end of the Tertiary, or to those of the post-Pliocene Himalaya. Many of the features of the Coast Ranges of California, a post-Pliocene uplift, are much more mature than those of the Atlas. It seems incredible to a geomorphologist that the youth and vigor of the Atlas could have survived from the time of the Alpine movement. He is at a loss to understand why they

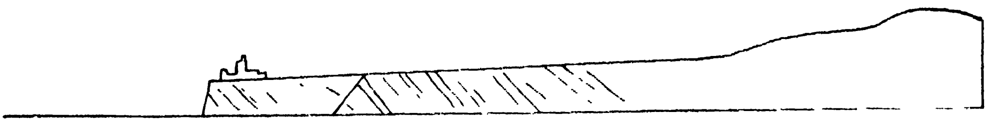


FIG. 2. UPLIFTED WAVE-CUT TERRACE

AT CAPE ST. VINCENT, PORTUGAL.

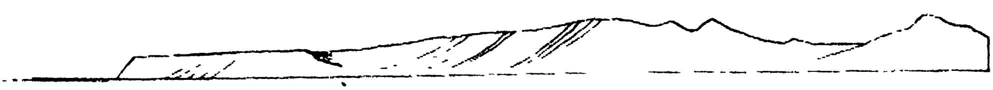


FIG. 3. UPLIFTED WAVE-CUT TERRACE

NEAR TARIFA, SPAIN.

FIG. 4. LOOKING FROM TANGIER TOWARD GIBRALTAR

SHOWING WAVE-CUT TERRACE 50 TO 65 M. HIGH

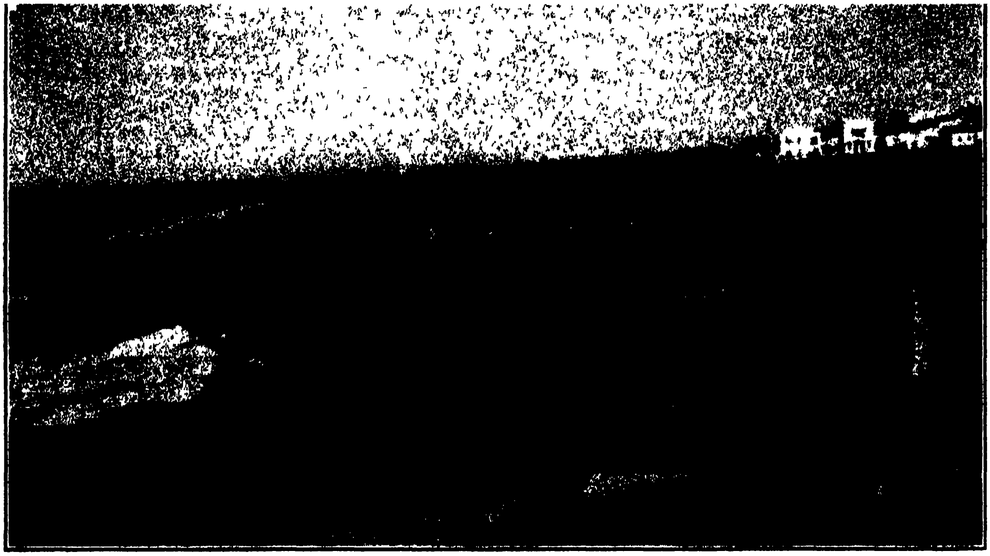


FIG. 5. SEAWARD DIP
OF WAVE-WASHED TERTIARY SANDSTONE, AT RABAT.

should have endured so long, when the much more extensive Hercynian Mountains, formed in the late Carboniferous in the same region, were reduced to a peneplain in time to receive a veneer of continental deposits in the Permian. For a range of such antiquity he expects wide valleys and rounded past-mature divides, graded streams and gentle, soil-covered slopes. Finding instead of these the incisiveness of new dissection, steep rocky canyon walls and, in the Anti Atlas, remnants of an overarching peneplain which truncates the Alpine structures, he is forced to the hypothesis of geologically recent rejuvenation. The formulation of this hypothesis and the partial exploitation of the evidence which supports it are based on an all too scant acquaintance with the region obtained by three visits to Morocco, comprising: (1) a trip to Spanish Morocco in 1926 as a participant in an excursion organized by the International Geological Congress, meeting at Madrid that year; (2) various excursions in Morocco, Algeria and Tunis in 1929; and (3) an excursion into the Atlas in 1930 under the leadership of Messrs. L. Neltner and E. Roch. Very little has been written concerning the geology of Morocco; but I have had the advantage of reading M. Neltner's typewritten guide for the excursion of 1930, and a very excellent treatise on the geography of the country by Hardy and Célérier.[1] The maps which have been available to me are: Maroc, Carte dressée et publiée par le Service Geographique du Maroc. Echelle au 1,000,000. Rabat 1930; Carte geologique provisoire du Maroc par Louis Gentil. 1:1,500,000 Paris 1920; Croquis geologique de la zone française du Maroc, 1:3,500,000, issued to the excursionists of 1930.

Much of the evidence to which I refer consists of facts well known to Moroccan geologists, but the conclusion deduced from that evidence, as to the rejuvenation of the Atlas, is new.

The evidence of uplift of the region northwest of the Atlas is very plain although its extent may not be easily

[1] "Les grandes lignes de la géographie du Maroc," 2e Ed. Paris, 1927.

defined. At Cape St. Vincent in southern Portugal sea-cliffs extending on either side of the cape for more than twenty miles reveal the structure of the formations which here make up the coast. The strata are folded, in places acutely and in others more gently; occasionally a fault may be observed. The cliffs are from 50 to 65 m high, and back from their brink a level bench land extends for some miles. The surface of this bench is very clearly one of horizontal corrasion (see Fig. 2); and since the coast is here exposed to the full sweep of the Atlantic, there can be little doubt but that it is a wave-cut terrace, the analogue of that now being rapidly cut at the base of the present sea-cliffs There are no deposits observable upon the abraded edges of the inclined strata at the bench level. There is no timber to obscure the view, and the terrace is covered with grassy vegetation. It rises very gently inland, and in the distance appears to have an altitude of perhaps 160 m. In side view from the southeast of the cape no steps are seen in the profile, and no well-defined sea-cliff could be made out at the back of the terrace, where it meets the hills On the south side of the cape the terrace is dissected by a few sharp ravines which bring the drainage to the shore. It seems certain that this portion of the Iberian peninsula has been uplifted, and that the measure of the uplift is the height of the rear of the terrace above sea-level, ignoring fluctuations of the latter The observation does not of course yield information as to the uniformity of the uplift or its extent.

The same physiographic evidence of uplift is observable on both sides of the Strait of Gibraltar, about 200 miles E S E of Cape St Vincent. On the Atlantic exposure of the north side of the strait in the vicinity of Tarifa a broad terrace slopes up very gently from the brink of the sea cliffs to the hills, truncating inclined strata. The profile is shown in the sketch, Fig. 3.

Similarly on the south side of the strait, in the vicinity of Tangier, there is a fine wave-cut terrace extending for two or three miles along the coast at an altitude of between 50 to 65 m The profile of this feature is well seen from Tangier from which the sketch in Fig. 4 was made

From Tangier south to the junction

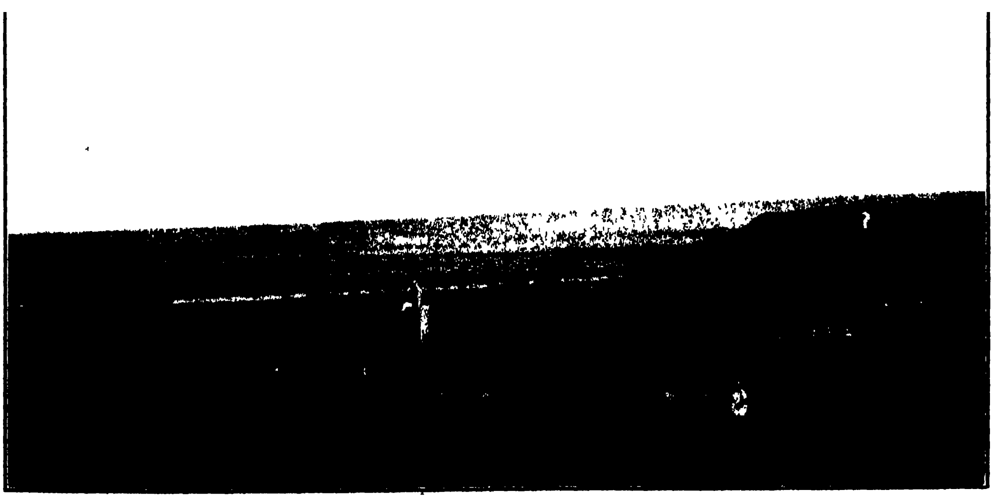


FIG. 6. THE MARITIME PLAIN

HERE A PENEPLAIN, LOOKING NORTH ACROSS THE RIVER BOU REGREG FROM RABAT.

FIG. 7. SETTAT
ON THE EDGE OF THE CENTRAL PLATEAU.

at Petitjean the railway crosses a well-defined, broadly dissected plain which slopes up eastward from the coast to elevations of over 65 m. This plain truncates folded Tertiary strata and is veneered locally with fluviatile gravels. It is traversed by six considerable streams flowing west to the Atlantic, five of them draining the western end of the Rif and the largest, the Sebou, draining by one of its branches the south flank of the Rif and by the other the north end of the Moyen Atlas. These streams in their lower reaches not only dissect the upland, but have evolved broad flood-plains along their courses. It appears probable that both wave and stream were concerned in the planation so apparent in this upland. Its present hypsometric position and its dissection prove the fact of uplift of at least 65 m. The full measure of uplift may be twice this.

The Tertiary sandstones underlying the plain are well exposed on the coast at Rabat as shown in Fig. 5. Here the seaward dip of the strata is much steeper than the slope of the plain. A fine view of the plain in profile from Rabat looking north across the river Bou Regreg is shown in the picture Fig. 6. There can be no doubt but that the surface shown here in profile truncates the strata of Fig. 5. The age of the strata is not known to the writer, but they are probably pre-Pliocene.

This stream dissected plain is the northern facies of the Maritime Plain which extends along the coast southwest of Rabat. The width of the Maritime Plain in the latitude of Petitjean is 75 km; at Settat it is 50 km and at Safi 25 km, beyond which it tapers out. It lies between the Central Plateau, which parallels the Atlas, and the Atlantic coast.

The feature of chief interest in the Maritime Plain is the veneer of marine Pliocene deposits which, with various interruptions and discontinuities, extends over its surface. The interruptions in the continuity of exposure of the Pliocene formations are due to: (1) High areas or inliers of the underlying basement from which the Pliocene beds have been removed by erosion, or upon which they were never deposited, as in the region between Rabat and the river Oum er Rbia; (2) Deltaic coverings of alluvium, as in the flood-plain of the

Sebou, and the ancient flood plain of a stream, now nearly defunct by capture, to the east of Safi; (3) ancient and modern sand dunes along the coast.

The inliers of the underlying basement consist chiefly of Paleozoic rocks with some rather notable and extended outcrops of the mantle of Permo-Trias red beds, which once covered the stumps of the Hercynian mountains throughout Morocco. Mesozoic marine rocks are generally absent from the basement upon which the Pliocene rests till we get as far south as Safi and as far west as Mazagan, at which points inliers of Cretaceous appear on the geological map.

South of Casablanca the Maritime Plain extends inland to the vicinity of Settat, where it ends at the base of a well-defined but maturely degraded scarp, which must have been the sea-cliff of the Pliocene sea. This ancient sea-cliff is here the northern limit of the Central Plateau, the drainage from which has indented the scarp with gullies and ravines. These do not, however, extend very far back in to the plateau, and in their upper reaches the streams flow in shallow trenches on its surface.

Near its outer edge, east of Settat (Fig. 7), the Central Plateau has an altitude of about 500 meters, and its precipitous front is about 200 meters high, rising abruptly from the plain. The Pliocene sea floor at the base of the ancient sea-cliff is thus about 300 meters above sea-level and this is a fair measure of the local uplift in post-Tertiary time. The uplift was by no means uniform, however, and it probably increases in amount toward the mountains, since Neltner[2] states that the marine Pliocene occurs at elevations of 500 meters.

The uplift indicated by these elevated Pliocene deposits was not limited to the close of the Tertiary. It has been a gradual movement and is still in progress. Beyond the southern limit of the Maritime Plain between Mogodor and Agadir, where the Grand Atlas extends to the coast, there are recent wave-cut terraces. At Cape Guir, where the Cretaceous strata are steeply inclined, there is a terrace 200 to 300 m wide, which, at the base of its complementary sea-cliff, still undegraded, has an elevation of about 50 meters. Above this there is a narrow terrace at about 65 meters; and below there is another at about 25 meters. The present sea-cliff is in active recession, and the mere existence of these elevated strands on a bold coast, exposed to the rapid corrasion of the open Atlantic, is ample proof of the recency of the uplift.

Away above the terraces just referred to there is a much older one at about

[2] MS text of guide for geological excursion of 1930.

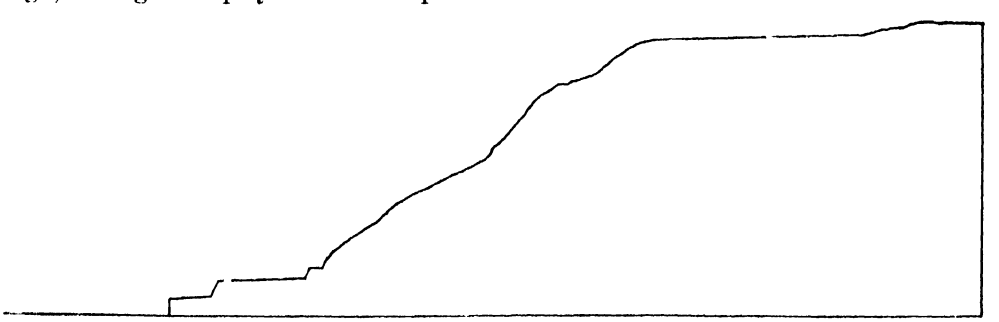


FIG. 8. PROFILE AT CAPE GUIR

SHOWING WAVE-CUT TERRACES.

380 meters truncating strata which dip south at angles of from 20° to 30°. This high terrace appears as a trench which has been cut in the seaward slope of a peneplain that extends over this end of the Atlas, and attains an altitude of over 700 meters. A sketch of an east-west profile through Cape Guir showing these features is given in Fig. 8.

In the valley of the Iguezoula north of Tamanar there is a fine display of wide stream terraces corresponding to the 50-meter marine terrace at Cape Guir. Below this is a narrow terrace at about 25 meters above the stream. Looking up this valley from a commanding point the upper terrace is seen to be a very extensive, wide valley floor ending in a gap in the skyline profile of a high dominating peneplain. The stream has a sinuous course through the old valley land. Since the terrace was the functional valley floor uplift has caused its dissection, and the present narrow stream gorge proclaims in eloquent terms its extreme youth.

On the way from Mogodor to Safi the road parallels the coast about 15 km inland. At about one third of the distance it climbs to a flat divide on the surface of a peneplain, and then descends to the valley of the river Tensift. The peneplain truncates folded rocks and is maturely dissected in its higher parts. A large area of it to the west of the road overlooks the sea, and the short streams in their lower reaches flow in sharp gorges. The general elevation of the surface near the coast is about 500 m Toward the south it rises to over 1,000 m and extends over the western end of the Atlas. It is probably a warped surface.

This upland, which may be conveniently called the Chiadma peneplain, is bounded on the north by the broad east-west valley of the Tensift, which drains the Grand Atlas south and east of Marrakech. On the north side of that valley the correlative of the Chiadma peneplain is the Central Plateau to which reference has already been made. This is a steppe land, with a dry steppe climate, thinly populated and more adapted for grazing than for tillage, and so presents a striking contrast to the fertile, more humid Maritime Plain. It lies between the Maritime Plain and the Atlas, but is separated from the mountains in its southern part by extended depressions at the base of the latter, in which are deployed the flood plains of the middle reaches of the Tensift and the Oum er Rbia. The Central Plateau extends northeast from the valley of the Tensift to the southern flanks of the Rif, where it is traversed by the Sebou River. In its northern part the distinction between the plateau and the Moyen Atlas is not easy since the surface of the former slopes up toward the mountains and extends over their flanks.

The rocks underlying the surface of the Central Plateau vary greatly in different parts of it; but they fall into three groups: (1) The greatly disturbed and altered Paleozoic rocks that make up the stumps of the Hercynian mountains; (2) the little disturbed Mesozoic and Eocene strata that lie nearly flat on the post-Hercynian peneplain, undeformed by the Alpine movement; (3) the Miocene deposits of the Meknès basin. The portions of the plateau best known to the writer are those traversed by the road from Casablanca to Marrakech, the phosphate mining district around Kourigha, and the region between Meknès and Taza. The higher parts of the plateau about the mines at Kourigha are occupied by an Eocene formation containing beds of phosphate of lime. These lie in nearly flat attitudes upon the Cretaceous formations, which in turn are seen at a number of places to rest upon the Permo-Trias, while the latter reposes upon the post-Hercynian peneplain. The Eocene of

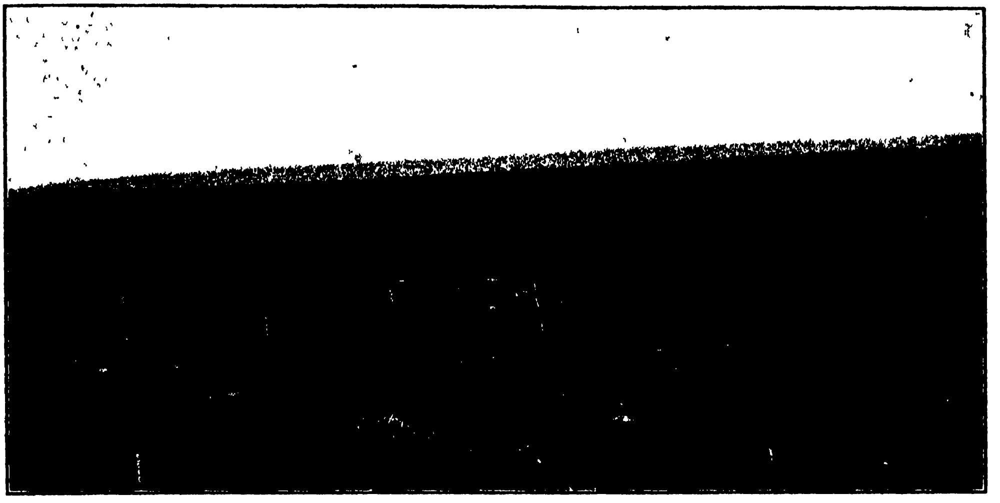


FIG. 9. THE CENTRAL PLATEAU EAST OF MEKNÈS

LOOKING SOUTH TOWARD BENI MGUILD.

Kourigha is a residual patch of a once much more extensive and thicker formation. A similar residual patch occupies much of the territory between Rehamna and Djebilet; and there are others to the south of the Tensift. The Cretaceous is a larger remnant. It once extended over much if not the whole of the areas in which the Paleozoic rocks now appear at the surface These areas are essentially the exhumed post-Hercynian peneplain, although of course the old surface has been modified somewhat since the Mesozoic cover was stripped away. Three areas of the post-Hercynian peneplain diversify the Central Plateau. They occupy a large part of the districts known as Zaian in the latitude of Casablanca, Rehamna south of the river Oum er Rbia and Djebilet north of the Tensift It is evident from the relief of the Rehamna where it emerges from below the Cretaceous that it was rather an uneven surface upon which the Mesozoic rocks were deposited, since some of the hills of Paleozoic rocks rise well above the present surface of the Cretaceous.

The removal of the greater part of the Eocene and the exhumation of the old pre-Permian surface has produced a post-Alpine peneplain which in part happens to almost coincide with the post-Hercynian one. The fact that this post-Alpine peneplain is so near the sea indicates that it was evolved close to the base-level of land erosion. The incisive sharpness of the inner gorge of the Oum er Rbia, which transects it, testifies to the recency of its uplift. The way in which the river traverses this high inlier of old hard rocks, in the midst of the flat lying residual Cretaceous, testifies also to the fact that it is a superimposed stream, the course of which was determined by the slope of the plateau when it was covered by higher Cretaceous or Eocene strata now removed. The uplift must, however, have had at least two stages. At the time of the emergence of the Pliocene sea floor, or the Maritime Plain, it was elevated through a minimum of 300 m It is doubtless this stage which finds its expression in the sharpness of the lower stream gorges. But when the scarp at Settat was a functional sea-cliff, the plateau at its seaward margin already had an altitude of 200 m. The geological date of this early stage of uplift was probably

FIG. 10. THE CITY OF FEZ

at the end of the Miocene, since the Miocene formations at the north end of the Central Plateau, in the Meknès basin, have no covering of marine Pliocene at the plateau level.

At Petitjean the railway leaves the Maritime Plain at an altitude of about 250 m and climbs south through the gorge of the river Rdom to the high plain on which Meknès is situated. At Meknès this surface has an altitude of about 500 m, but it rises very gently to the south through another 500 m, and then steps up 100 m by a degraded scarp to the limestone plateau of Beni Mguild (see Fig. 9). The latter in turn by steepening slopes grades into the sides of the Moyen Atlas. The rocks underlying the Meknès-Fez plain are partly soft marine Tertiary beds and partly lake beds. The plain extends eastward through the pass of Taza without important change of level to the valley of the Moulouya. It is a surface of erosion evolved at low levels, and now dissected by streams as a result of uplift. Between Fez (Fig. 10) and Taza the most important route of travel in Morocco passes between the Rif and the Moyen Atlas through a broadly terraced valley, narrowing eastward. Beyond Taza the country opens out upon a broad desert traversed by the terraced canyons of the Moulouya and its tributaries. The flat surface of the desert is an uplifted flood plain of the river, and to the south one gets distant views of a still higher peneplain, as shown in Fig. 11, a picture of the country looking southeast from the hotel at Taza.

The Meknès basin including its extension eastward through the pass of Taza, is superficially distinct from the rest of the Central Plateau by the difference in its underlying formations, and by the fact that a monadnock of the old Hercynian peneplain in the Zaïan seems to break the continuity of the plateau surface. But since it has the same general altitude as the country southeast of the monadnock, and is an erosional surface which acquired that altitude by uplift in the same way and at the same times as the Central Plateau, it may properly be regarded morphologically as part of the latter.

The physiographic evidence of post-Tertiary uplift is not confined to the northwest side of the Atlas. The uplifted, dissected and terraced flood plain of the Moulouya not only extends north to the Mediterranean through the Tell, a region of small isolated mountains of folded Mesozoic strata, but up stream it extends through high plateaux into the acute reëntrant between the Moyen Atlas and the north end of the Grand Atlas The plateaux of Jurassic and Cretaceous strata which enclose it slope up to the Moyen Atlas on one side and to the Grand Atlas on the other in a synclinal disposition. In this syncline the latest geological map[3] shows a basin of Miocene formations at altitudes of over 1,000 m. This basin of soft Miocene beds, lying in a broad syncline of harder rocks, has determined the widening of the flood plain of the river above its constriction at the northeast end of the Moyen Atlas.

Concerning the vast plateaux at altitudes of over 1,000 m, which lie on the continental side of the Atlas, extending east into Algeria and south toward, if not into the Sahara, we have but meager information. The high Plain of Tamlelt, which at an altitude of nearly 2,000 m divides the drainage to the Mediterranean from that into the Saraha, appears to be a broad structural arch feebly folded and broken along its axis The axial region is shown on the geological map to be occupied by Lias and Jurassic formations, while the extensive nearly flat slopes to the north and to the south are Cretaceous. At the foot of the

[3] Scale, 1:3,500,000 issued without date to participants in the geological excursion of 1930.

FIG. 11. A VIEW SOUTHEAST FROM TAZA
SHOWING A HIGH PENEPLAIN.

northern slope the Cretaceous lies again upon the Jurassic in the Gada Debdou, which presents an escarpment to the ancient flood plain of the Moulouya. The shallow Cretaceous syncline thus located in the middle slope is the same as that in which the basin of Miocene lies in the upper Moulouya The anticlinal arch of Tamlelt serves to establish orogenic continuity between the Grand Atlas and the ranges of southern Algeria Since the folding, however broad and gentle, which gave rise to this connecting geanticline is pre-Miocene in age, it may safely be regarded as a product of the Alpine movement. The surface of the plateau, which thus stretches from Gada Debdou to Tamlelt and from the end of the Grand Atlas into Algeria, is a surface of erosion which truncates indifferently the various formations of the Lias, Jurassic and Cretaceous. It is therefore a very perfect peneplain which has recently been uplifted; since, being so near the Mediterranean, it could not have been formed at the present altitude. It is now in the initial stages of dissection by vertical corrasion. Had the uplift been of ancient date, in a geological sense, the dissection would have been far advanced; and the plateau, if it still retained its altitude, would do so only as an aggregate of buttes and mesas.

The Anti Atlas is separated from the south end of the Grand Atlas by the valley of the river Sous (Fig. 12) and connected with it by the high but much degraded volcanic pile of Siroua about 200 km east of Agadir. It consists of folded Mesozoic strata resting unconformably upon more intensely deformed Paleozoic rocks, and appears to have had the same orogenic history as the Grand Atlas On the road between Taroudant on the Sous River and Igherm, a military and administrative post on the south side of the crest, excellent views are obtained of the rocks, the tectonic features and the geomorphy of the range. The most notable feature observed, from the point of view of the present discussion, is an extensive peneplain, remnants of which extend well over the Anti Atlas. The wide-spread truncation of the folded Mesozoic strata is surprisingly clear on the northern flank of the range, where it is seen to slope down toward the valley of the Sous; and it appears that the dislocation

of this peneplain by faulting along the southern flank of the Grand Atlas is the most probable origin of the valley of the Sous. The attitude of the peneplain on the south flank of the Anti Atlas is unknown, but it seems probable that this interesting feature arches over the range and slopes down to the Sahara.

From the foregoing observations we may conclude that the Anti Atlas of Oligocene time was reduced by the prolonged erosion of the later Tertiary to a surface of low relief, which traversed indifferently both its Alpine and its Hercynian structures, and that the range as we know it to-day is the result of the uplift of that surface, probably in the form of an arch, and the sculpture by erosion of the uplifted mass.

In general the various plateaux which surround the Atlas Mountains, and in part extend over them, are remnants of an extensive peneplain of post-Alpine origin which has been uplifted by arching, and in part dislocated by faulting, in late Tertiary and Quaternary time. The maximum uplift of these plateaux is at the margin of the mountains or, in the case of the Anti Atlas, along the axis of the range. In the Moyen Atlas they extend well up on the flanks of the range to levels above which they have been obliterated by erosion; in the Grand Atlas the projection of their surfaces abuts upon the very steep mountain fronts, where large faults dominate the geomorphic features. The most notable of these marginal fault zones is that which limits the Grand Atlas along the front overlooking the Haouz of Marrakech, a structural trough formed by the sinking of a broad belt of the Central Plateau along the northern border of the range. Here the mountains rise abruptly from the lowland of the Haouz in what appears from a distance to be a

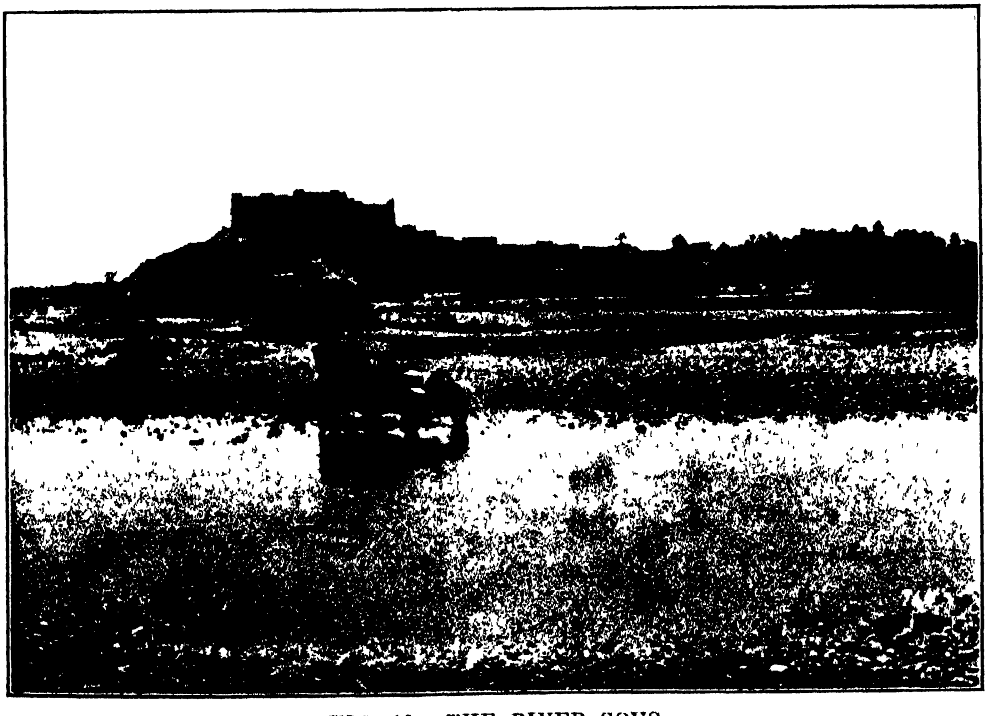


FIG. 12. THE RIVER SOUS

BETWEEN THE GRAND ATLAS AND THE ANTI ATLAS.

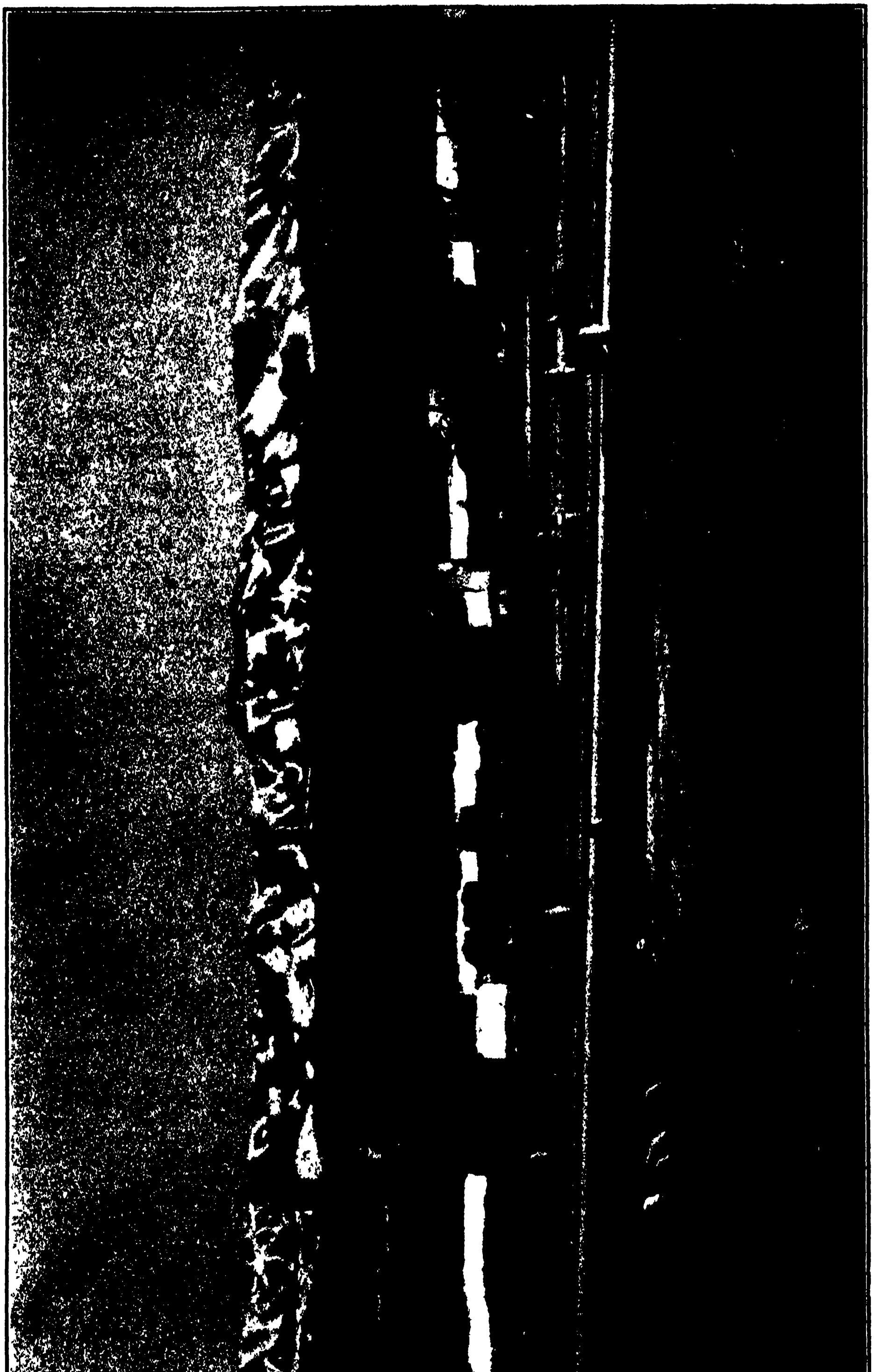


FIG. 13. THE GRAND ATLAS
LOOKING ACROSS THE HAOUZ OF MARRAKECH.

great wall as shown in the pictures, Figs. 13 and 14. The effect is not unlike that of the eastern front of the Sierra Nevada of California, and geologists are agreed that it is due to a great dislocation of the earth's crust. Just within the mountain front on the road from Marrakech to Azni several minor faults of the zone may be seen at close quarters. They are steep normal faults with downthrow to the north, and the drag in the thinly stratified rocks is well displayed on the side of the canyon.

The Haouz is filled with fluviatile detritus (see Fig. 15), the depth of which is not apparent, and the surface of the fill is now the flood plain of the Tensift and its numerous torrential tributaries. A similar depression, known as the Tadla, lies at the base of the south end of the Moyen Atlas, and although the mountain slope is here much more subdued, a zone of faulting is mapped by Gentil[4] at the base of the range northeast of Kenifra, which suggests that the front of the Moyen Atlas may also be defined by a fault, analogous to that of the Grand Atlas. Gentil's fault zone if prolonged would not only drop the south border of the Central Plateau against the Moyen Atlas, but would serve also as the southern boundary of the depression to the north of the Djebilet, which is the westward extension of the Tadla. That the combined depression of the Haouz and Tadla is structurally double appears from the fact that the continuity of the two is offset to correspond with the reëntrant between the south end of the Moyen Atlas and the Grand Atlas.

The peneplain of the Central Plateau once extended to the present front of the Atlas across the existing troughs of the Haouz and the Tadla before the depression was inaugurated (see Fig. 16), just as it still does on the south side of the Tensift near the coast, and north of the Tadla. The projection of its surface over those depressions would intersect the steep profile of the Atlas at an altitude of about 1,200 m. Before the uplift of the peneplain we may suppose that in late Tertiary time the Atlas of Alpine origin had been reduced to a residual hill range of past-mature slopes, having an altitude of perhaps 600 m. The effect of the uplift of the region in a great arch, affecting both peneplain and hills, would be to elevate the latter through about 1,400 m, giving them an altitude of about 2,000 m and subjecting them to vigorous vertical corrasion.

It is convenient in analysis to think of the general arching of the region as having preceded the more local and intensive upthrust to which the present configuration of the Atlas is primarily due. But, as will appear in the sequel, the arching may have been synchronous with the orogenic upthrust, and indeed due to it. However that may be, it is clear that the two movements, general or epeirogenic arching and local or orogenic upthrust, were involved in the rejuvenation of the range. From the preceding cycle, in which the Alpine Atlas was reduced to residual hills, it is certain that the new range would have inherited a shear stress on both flanks. As a relief from this stress marginal faults had long since been developed and it was between these that the upthrust, due to orogenic forces of compression, was localized. The rapid degradation of the upthrust mass and its consequent loss of load, would induce a still farther rise of the range, and this rise is still going on It is this supplementary rise due to isostatic adjustment, which, by causing a withdrawal of heavy rock in depths from the flanking regions, explains the origin of such depressions as the Haouz of Marrakech, the Tadla and the Sous. The evidence of the latest phase of this movement consists of a system of stream terraces which are ob-

[4] Carte géologique provisoire du Maroc, 1920.

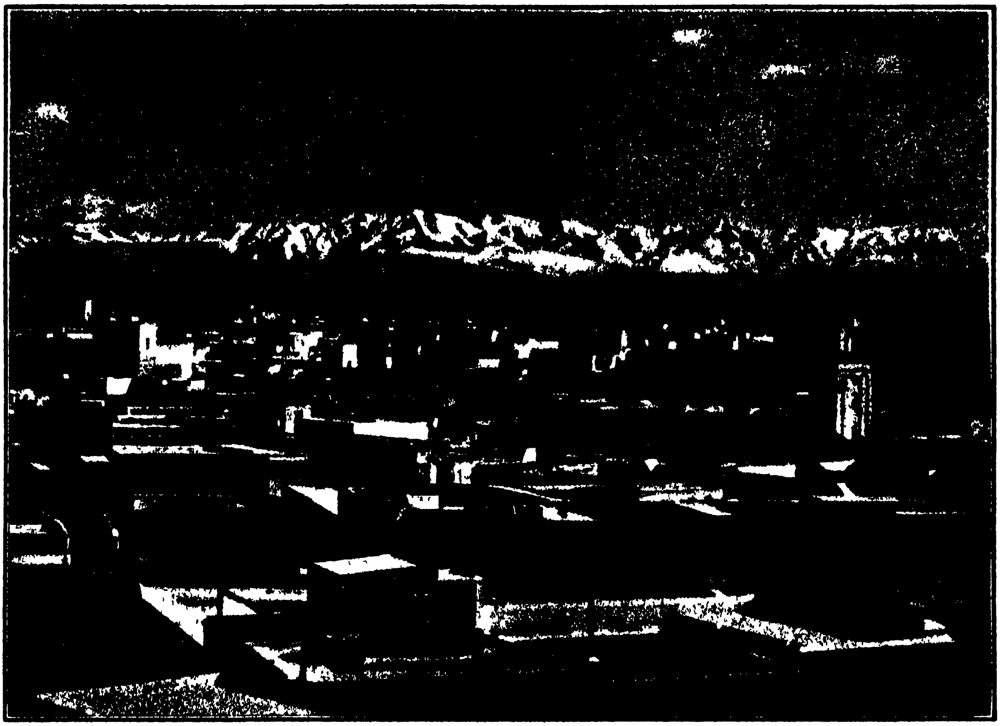


FIG. 14. THE GRAND ATLAS
LOOKING OVER THE CITY OF MARRAKECH.

FIG. 15. THE ALLUVIAL PLAIN
OF THE HAOUZ OF MARRAKECH.

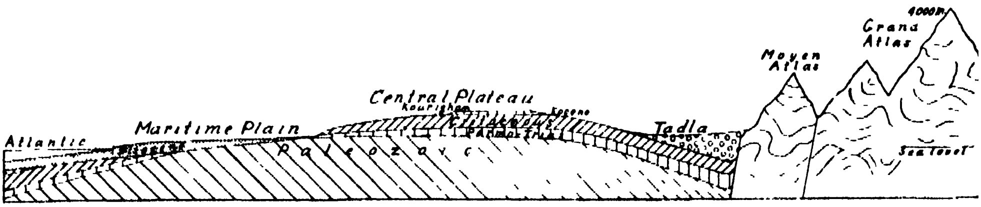


FIG. 16. HYPOTHETICAL SECTION

ACROSS THE MARITIME PLAIN, THE CENTRAL PLATEAU, THE TADLA, AND THE ATLAS.

servable in many of the great canyons at altitudes of from 65 m to 85 m above the streams, and in terraces at the front of the range which appear to be uplifted portions of the flood plains of the streams now dissecting them, as exemplified at the mouth of the canyon followed by the road from Marrakech to Azni (Fig. 17).

The doctrine of isostasy in its extreme form teaches that the Atlas is the top of a column of the earth's crust which is in balance with other neighboring columns the tops of which are much nearer sea-level or, indeed, below it. The areal limits within which the principle of isostasy applies is, however, as yet uncertain owing to the fact that the rigidity of the crust interferes with its operation, the measure of that rigidity being unknown. It is desirable, however, in any discussion of the genesis of a great mountain range to at least consider the possible rôle played by isostasy in its historical development and in its reduction under erosion. The remarkable depressions of the Haouz and Tadla on the north side of the Grand Atlas, and that of the valley of the Sous on the south side, are suggestive of a transfer of mass in depth from the sides of the range to its base, to compensate for its loss of load by erosion; and a brief discussion of this possibility may be of interest. For the sake of clearness in treatment I shall assume the validity of isostasy as applied to the Atlas and present the considerations involved rather dogmatically.

I shall begin by stating again that the Atlas as we know it to-day is due to the operation of a late Tertiary or post-Tertiary collapse of the earth's crust under excessive compressive stress. This stress was not isostatic, but the concentration of mass which gave rise to the range proceeded under the control of isostasy. That is to say, while the crowding together of the rocks of the sial tended to disturb the balance, that tendency was never very effective owing to the fact that the upthrust, due to horizontal compression, was compensated by a much larger downthrust into the sima below the growing range. In this way the range maintained its buoyancy, and the total mass of the column from the summit, at all stages of its

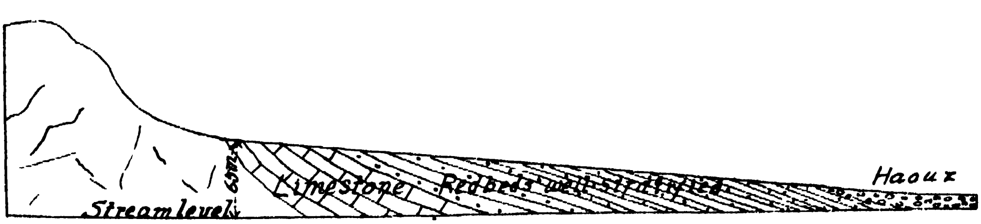


FIG. 17. STREAM TERRACE

AT THE FRONT OF THE GRAND ATLAS ON THE ROAD FROM MARRAKECH TO AZNI.

genesis, down to the zone of compensation remained constant and in balance with neighboring columns not directly affected by the collapse. If the sial be supposed to be 20 km thick from sea-level down, with a mean specific gravity of 2.7, and to rest upon a layer of sima 20 km thick with a specific gravity of 3, then for every kilometer of upthrust there would be 9 kilometers of downthrust into the sima. The mountains are thus a prism of sial floating in sima, just as ice floats in water, except for the great difference in viscosity. If the orogenic upthrust had been say 1 km in the Grand Atlas, then the downthrust of the same light rocks into the sima would have been 9 km. If the width of the Atlas be taken at 50 km, then a prism of sima 50 x 9 km in cross-section was displaced by this downthrust. The greater part of this prism, distributed by rock flow into the adjoining regions, would have caused an uplift or flat arching of the earth's crust. If such an arch had a maximum uplift of 1 km at the mountains it would have extended out on either side of them for a distance of 400 km, there tapering out to nothing. This redistribution of sima from below the Atlas, at the time of the upthrust about the end of the Tertiary, may well have been the cause of the arching of the peneplain surrounding the residual Alpine Atlas. In the discussion that arching was separated for convenience from the upthrust but the two movements may have been intimately connected genetically. The added load due to the redistribution of the displaced sima would of course have tended to disturb the balance of the earth as a whole, and would have necessitated an isostatic adjustment of the entire spheroid.

As the upthrust proceeded the Atlas would loose load by erosion, but we may consider the effect of this erosion more conveniently by thinking of the orogenic upthrust having been completed before erosion began its work of degradation. The upthrust was effectively a dislocation of the residual hills of the Alpine Atlas from the adjoining peneplain and a rejuvenation of the old worn-down mountains. If we reduce the hills, as they may be pictured after arching and before upthrust, to a uniformly level surface, they would have had an altitude of about 1,600 m. Let p be the amount of vertical upthrust, then $1{,}600 + p$ would be the value for the effective height of the Atlas before erosion, or the height at which the range would now stand if there had been no degradation. The mean crest line of the Atlas to-day is about 3,800 m, and the mean stream level is about 1,000 m above sea-level. Since the canyons are V-shaped and the crests are generally sharp, due to intersection of canyon walls, $1{,}000 + \frac{3{,}800 - 1{,}000}{2} = 2{,}400$ m is the height of a level topped prism equal to the present mass of the Atlas above sea-level. The loss of height as a result of erosion of the upthrust column is thus $1{,}600 + p - 2{,}400$ or $p - 800$ m. But there is a simple relation between the loss of height and the thickness of the effective prism removed. For every 1 removed there is a rise of the column of 2.7/3 or 9/10 and a loss of height of 1/10. Therefore the effective prism removed is $10(p - 800)$ m. In the case of the Atlas there are no observational data from which the value of p may be derived. But it may be of interest to examine the consequences of an assumed value. Suppose, for example, that p were 1,000 m. Then the loss of height $p - 800$ would be 200 m, and the rise of the column, $9(p - 800)$, would be 1,800 m. The rise of the column is effected by an inflow of sima from the adjoining regions to the bottom of the column. The prism of sima thus inserted is 1,800 m thick. Half

of this came from under the Haouz and half from the south side of the Atlas. Considering the Haouz of the same width as the Atlas a prism effectively 900 meters thick for that width was withdrawn from under it. But the prism was probably wedge-shaped in cross-section, tapering out to nothing on the far side of the Haouz. At the border of the mountain column therefore it had a thickness of 1,800 m The downthrow of the peneplain to form the depression of the Haouz was thus 1,800 m, and the alluvial deposit which occupies the depression has a thickness of 1,200 meters near the mountains where its top is 600 m above sea-level.

But small changes in the assumed value of the orogenic upthrust make large differences in these results. Thus if we make $p = 900$ m instead of 1,000 m, then the loss of height for the effective level-topped prism becomes 100 m, the effective prism removed 1,000 m, the rise of the column 900 m, the downthrow on the north side of the mountains 900 m and the thickness of the alluvium on the south side of the Haouz 300 m

Owing to the uncertainty of the assumptions made the figures have little value except that they illuminate the geological implications of the doctrine of isostasy as applied to great mountain ranges. If the thickness of the alluvium in the Haouz were known as the result of boring operations near the border of the mountains the value of p would also be determined. Similarly, if a geomorphologist should some day discover on the crest of the Grand Atlas remnants of the uplifted worn-down surface of the residual Alpine Atlas, corresponding to the remnants of the peneplain so apparent on the summits of the Anti Atlas, then the value of p would be 940 m, the rise of the column under erosion would be 1,260 m and the thickness of the alluvium on the south side of the Haouz 660 m.

Summary

The Hercynian mountains, extending over a very much larger region than the Atlas, were reduced to a peneplain upon which were spread the continental fanglomerates, red beds, etc., of the Permo-Trias In a geosynclinal depression of this veneered peneplain there were deposited great thicknesses of Liassic, Jurassic, Cretaceous and Eocene marine formations. At the time of the Alpine Revolution, about the end of the Eocene, the collapse of this geosyncline by compressive stress gave rise to the Alpine Atlas. By the end of the Tertiary the latter had been reduced to a past-mature hill range and the surrounding country to a peneplain. The rejuvenation of this hill land into the present Atlas is due to two distinct movements. A broad arching in at least two stages which lifted the peneplain near the mountains to about 1,200 m above sea-level; and a sharp orogenic upthrust, between marginal faults inherited from the preceding cycle The degradation of the upthrust mass and consequent loss of load induced farther rise by isostatic adjustment. The depressions flanking the range are explained as due to withdrawal of material in depth to compensate the range for its loss of load.


Antonj van Leeuwenhoek

ON THE TRAIL OF VAN LEEUWENHOEK

By Dr. JOHN BETHUNE STEIN

DEPARTMENT OF PHYSIOLOGY, NEW YORK UNIVERSITY, COLLEGE OF DENTISTRY

THE father of microscopy, Antony van Leeuwenhoek, the son of Philip van Leeuwenhoek and Margaretha Bel van den Bergh, born at Delft, October 24, 1632, was a pioneer in biology, and through him new sciences saw the day. Van Leeuwenhoek was descended from a family of brewers. His father having died during his childhood, he was sent by his mother to the village school at Warmond, where he obtained his early education. Later he went to Benthuizen with the intention of preparing for a position in the municipal government of that city, his uncle being the secretary of the administration. At sixteen he was apprenticed to a draper at Amsterdam, whose cashier and bookkeeper he soon became, and here it was he learned to use the magnifying glass which drapers then employed for counting the threads in their goods. It is highly probable that this led him to study optical instruments and to make the microscopes and the great discoveries which made him famous. After spending some years in the drapery business he returned to Delft and married Barbara de Mey, on July 26, 1654. Five children were the result of this union; a daughter, Maria, survived him. His wife died twelve years after this marriage. His second wife was Cornelia Swalmius. The issue of this marriage was a girl who died early in life. At Delft he became "Kamerbewaarder der Kamer van Heeren Schepenen van Delft," a position neither ardouous nor exacting, which he held for thirty-nine years and which enabled him to devote a great part of his time to work of his own selection.[1]

Van Leeuwenhoek's house still exists at Delft, says Haaxman. It is No. 455, on the corner of Botersteeg and Oude Delft, Wijk 4. The façade is changed, but the side and rear of the house remain unaltered.[1]

"In the year 1673," Quekett tells us, "the name of the immortal Van Leeuwenhoek first appears in the *Philosophical Transactions* of this country [England], as a discoverer of numerous wonders by the aid of the microscope; his instruments, which were composed of single lenses, are said to have been superior to all that had been previously made."[2]

Van Leeuwenhoek constructed his microscopes and lenses, and asserted the latter must be of exceptionally fine rock crystal. The essentials in which his microscopes surpassed all others were in his knowledge of grinding, polishing and mounting the lenses, so that no one could compete with him His microscopes were mechanically rough and were made especially for the examination of one, two or three objects. Most of his lenses had a quarter-inch focus and were mounted between two thin plates either of copper or silver-bronze or silver or gold. The magnifying power of his microscopes varied apparently between forty and two hundred and seventy diameters. The museum at Utrecht contains, says Harting, a microscope made by Van Leeuwenhoek which magnifies two hundred and seventy diameters. This instrument magnifies more than did any of the twenty-six microscopes bequeathed by Van Leeuwenhoek to the Royal Society of England which were carried to London by Martin

[1] P. J. Haaxman, "De Ontdeker der Infusorien," S. C. van Doesburgh, Leiden, 1875.

[2] J. Quekett, "Practical Treatise on the Use of the Microscope," H. Bailliere, London, 1855.

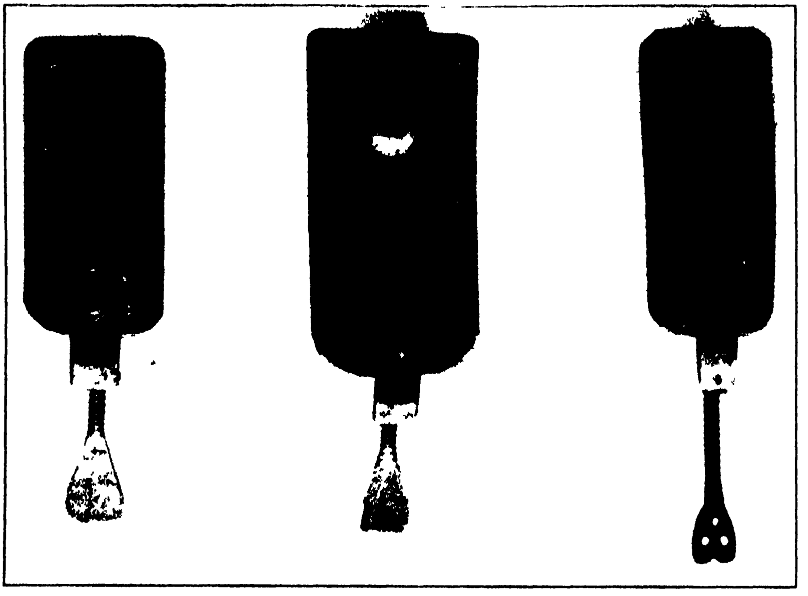


FIG. 2. FRONT VIEWS OF THREE MICROSCOPES

MADE BY VAN LEEUWENHOEK, WHICH ARE EXHIBITED AT THE RIJKS MUSEUM VAN OUDEHEDEN AT LEYDEN, HOLLAND. THE PHOTOGRAPHS SHOW THE EXACT SIZE OF THE MICROSCOPES.

Folkes, a president of the society, and which have mysteriously disappeared. According to Baker, who examined these microscopes, the highest magnifying power was one hundred and sixty diameters and the lowest forty.[1,2,3,4,5]

Henry Baker (1692–1774) was an English naturalist, an authority on microscopes, the author of "The Microscope Made Easy" and "Employment for the Microscope," a member of the Royal Society of England and the recipient of the Copley gold medal of this society for "Microscopical Observations on the Crystallization of Saline Particles." Baker had these twenty-six microscopes in his care for three years and says they were very serviceable. A description of the microscopes made by Van Leeuwenhoek was written by Baker in 1740, and was published in the *Philosophical Transactions* of the Royal Society of England of that year. Baker says:

> All the parts of these microscopes are of silver, and fashioned by Mr. Leeuwenhoek's own hand, and the glasses, which are excellent, were all ground and set by himself, each instrument being devoted to one or two objects only, and could be applied to nothing else. This method induced him to make a microscope with a glass adapted to almost every object, till he had got some hundreds of them.[2]

The three photographs (Figs. 2, 3 and 4) form the nucleus of my paper. They show several views of three microscopes constructed by Van Leeuwenhoek. These microscopes are exhibited at the Rijks Museum van Oudheden at Leyden, Holland. I am greatly indebted to Dr. A. E. J. Holwerda, the director of the Rijks Museum van Oudheden, for his interest and great care in obtaining these photographs for me.

Dr. Holwerda has written me that microscopes invented by Van Leeuwenhoek are in the possession of Mr. F. A.

3 P. E. Launois, "Les Pères de la Biologie," C. Maud, Paris, 1904.

4 W. B. Carpenter, "The Microscope and its Revelations," J. and A. Churchill, London, 1891.

5 Daremberg, C. "Histoire des Sciences, Médicales," J. B. Baillière et Fils, Paris, 1870.

Haaxman, a resident of The Hague, 2 Schuystraat, No. 114. Only two other microscopes made by Van Leeuwenhoek still exist, to my knowledge—one is at Gouda and the other at Utrecht.

My description of the photographs seen in Figs. 2, 3 and 4 is substantially the same as that given by Baker of his drawings in 1740.[2] Front views are seen in Fig. 2; rear views in Fig. 3, and oblique and side views in Fig. 4, all being the exact size of the instruments. Two plates are riveted (best seen in Fig. 4 at right). Between these plates a small biconvex lens is let into the socket, and a hole drilled in each plate for the eye to look through the lens. A limb of metal bent at right angles is fastened to the plates by a screw (Fig. 2). Through this bent limb of metal a long fine-threaded screw (Figs. 3 and 4) runs which turns in and raises or lowers the stage whereon is fastened a pin for the object to be attached to. This pin can be turned about by a little handle (best seen in the photographs left and right of Fig. 3 and the left in Fig. 4). The stage itself is adjusted to or from the lens by another larger screw which passes through the stage in a horizontal position, and when the screw is turned, the stage is forced from (at left in Fig. 4) or brought nearer to (at right in Fig. 4) the lens. If the object to be examined was solid it was placed upon the end of the pin, but if fluid it was placed upon a thin glass or mica plate and fastened to the object holder by wax or glue.

Figs. 5 and 6 (from Baker) show the front and rear views respectively of a silver-bronze microscope made by Van Leeuwenhoek. This microscope had two lenses (c-c), so that similar or dissimilar objects might be examined by him in sequence and thus be readily compared.

Carpenter says of the microscopes made by Van Leeuwenhoek that "nothing was known of his instruments except that they were simple microscopes even down to so late as 1709."[4] "Is it not strange," says Harting, "that the dis-

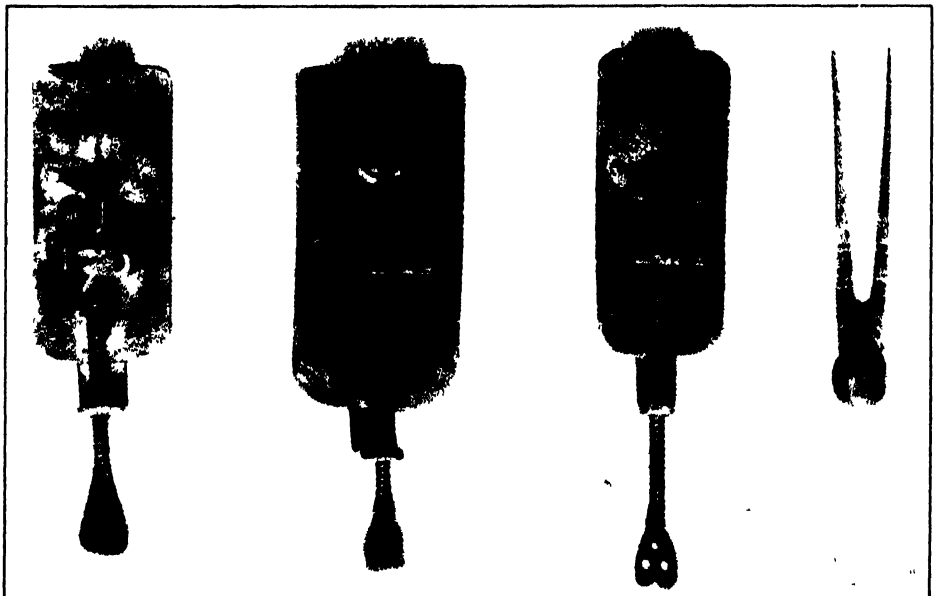


FIG. 3. REAR VIEWS OF THE SAME

A SMALL INSTRUMENT IS SEEN AT THE RIGHT.

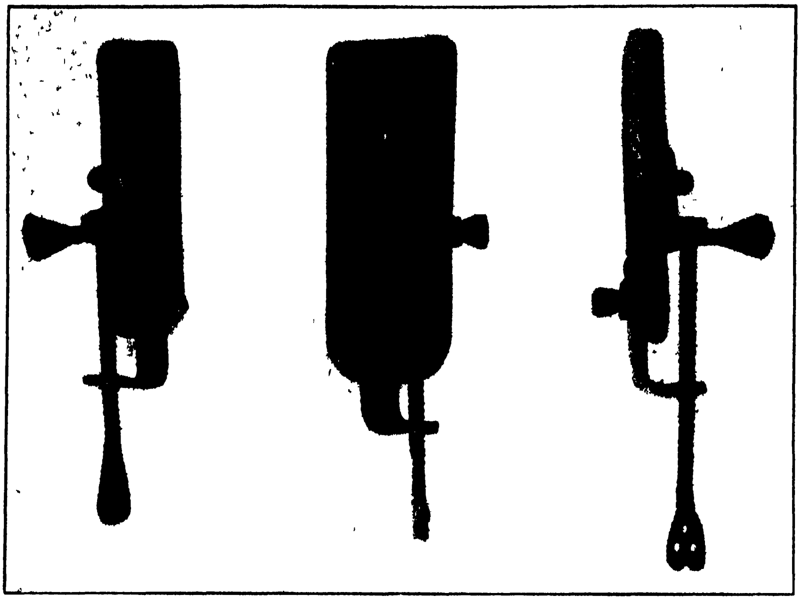


FIG. 4. OBLIQUE AND SIDE VIEWS

covery of an instrument so inherently necessary for the investigation of an entirely new world should attract so little attention that for years its existence was but little known outside of the walls of the house of its inventor?"[1]

Van Leeuwenhoek had several standards for measuring objects with the microscope, one being a grain of sand which measured arbitrarily, according to him, one thirtieth of the thickness of a thumb. He sometimes compared the size of an object either to that of a millet seed or a grain of wheat or to the thickness of a hair of the head or beard After he had discovered the erythrocyte of man he took its diameter as his standard of measurement.[5]

On August 15, 1673, while examining his blood, Van Leeuwenhoek found it consisted of a transparent fluid in which little solid bodies were suspended. These bodies he called globules, and he noted that the color of the blood depended upon them. This discovery was transmitted to the Royal Society on April 24, 1674. Later he found that these globules were disk-shaped, and he called them blood disks (bloedschijfjes). One hundred mammalian blood disks in a row, according to him, were equal to the diameter of a grain of sand or one thirtieth the width of a thumb, and one disk was equal to two thousandth of the width of a thumb.[1] He examined the blood of the ox, sheep and rabbit, and of fishes, birds and reptiles. He called the mammalian erythrocytes globules because when he first saw them he thought they were spherical. He designated the erythrocytes of birds, reptiles and fishes particles because of their flattened oval appearance. His drawings attest that he distinguished a nucleus in each particle. He described the distortion and compression of the erythrocytes as they pass through the capillaries, noticed that upon the addition of water the erythrocytes changed their shape and saw that the area at the center of the mammalian erythrocyte was lighter in color.[6]

He was not the first to discover the erythrocyte. Kirscher in 1650 had written of having seen little bodies, which he described as little worms, in the blood of patients suffering from fever. Swam-

merdam saw the frog's erythrocyte in 1658, but did not publish his discovery. Malpighi in 1661 saw the hedgehog's erythrocytes but mistook them for fat globules.

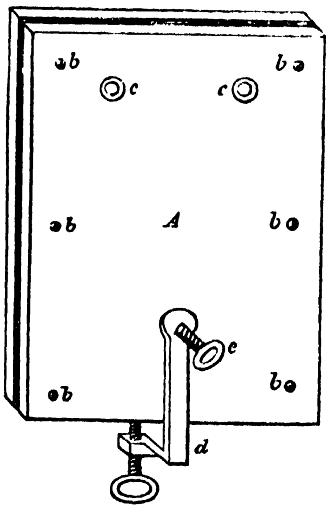
In a letter to L. van Velthuyzen, May 11, 1679, Van Leeuwenhoek complained of the little help he obtained from his scientific colleagues in Delft. "I have now and then made known that I was anxious to examine the blood of sick persons, but I have never been able to obtain any such blood, therefore I have made no further examination of the blood"[1]

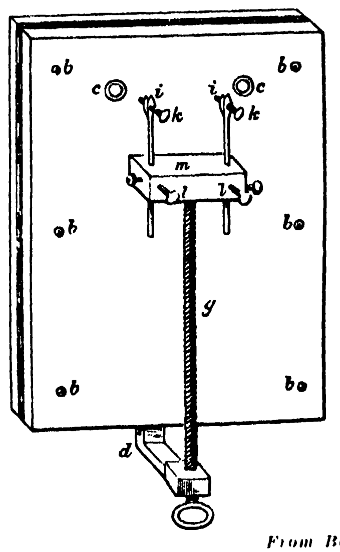
Van Leeuwenhoek recognized the canals in bone, afterwards called Haversian canals, and the bone cells in their lacunae; he notified the Royal Society in 1674 that bone consisted of little balls, "bolletjes"; but in 1678 he changed his opinion. He then said the little balls were the ends of "little tubes" and that dried bone consisted of different kinds of tubes.[1]

He was very sensitive of any distrust concerning his discoveries and in a letter to the Royal Society said:

> Whenever I am in doubt or question what I see I say so. Many can not understand my writings and frankly say they do not believe me. I console myself because I try to discover facts only. As soon as I find that I have made a mistake I am always willing to recognize it.[1]

In 1674 when Van Leeuwenhoek was forty-one years old, the anatomist Reinier de Graaf (1641 73), appreciating the value of Van Leeuwenhoek's discoveries, which were known only to a small circle, entreated him to write of some. This Van Leeuwenhoek did, and his thesis entitled "A Specimen of Some Observations Made by a Microscope Contrived by Mr. Van Leeuwenhoek, Concerning Mould upon the Skin, Flesh,





From Baker

FIG. 5. FRONT VIEW OF A SILVER-BRONZE MICROSCOPE

MADE BY VAN LEEUWENHOEK. LITTLE HOLES WERE DRILLED THROUGH THE PLATES AT c–c, THE PLATES HOLLOWED OUT AT THESE SPOTS AND BICONVEX LENSES PLACED IN THE HOLLOWS AND THE PLATES RIVETED.

FIG. 6. REAR VIEW OF FIG 5

THE OBJECTS FOR EXAMINATION WERE FASTENED ON THE PINS i–i WHICH COULD BE TURNED BY THE HANDLES k-k. TWO OBJECTS COULD BE BROUGHT INTO PROPER POSITION BEFORE THE LENSES c–c BY THE SCREWS g–l–l-k-k. SIMILAR OR DISSIMILAR OBJECTS COULD BE EXAMINED IN SEQUENCE BY VAN LEEUWENHOEK.

—From Hausman

FIG. 7. THE MEDAL PRESENTED VAN LEEUWENHOEK

BY THE ROYAL SOCIETY IN 1679, WHEN HE BECAME A MEMBER OF THIS SOCIETY. LEFT: A MEDALLION OF VAN LEEUWENHOEK IS SEEN. RIGHT: ILLUSTRATIONS OF A PLANT, A BEE-HIVE AND THE CITY OF DELFT, WITH A QUOTATION FROM VERGIL

etc., the Sting of a Bee, etc.'' was read by De Graaf at the meeting of the Royal Society of England on May 19, 1675.[1] For nearly fifty years thereafter Van Leeuwenhoek continued transmitting to the Royal Society accounts of his discoveries, often accompanied with illustrations. He sent one hundred and ten communications to this society and twenty-seven to the French Academy of Sciences. As he had no knowledge of any language except his own he wrote in Dutch and had his writings translated into Latin.

Van Leeuwenhoek was the first to see living micro-organisms. In fact he is regarded as the discoverer of both bacteria and infusoria. He announced to the Royal Society (October 9, 1676) that he had discovered what he called animalcules (zeer kleine dierkens), in rain, snow, well and other waters, also in water in which pepper or ginger had been soaked. In a letter to Constantin Huygens, dated November 7, 1676, he says that about the middle of September, 1675, he had discovered animalcules in rain-water which had stood in a barrel for several days, and that they were ten thousand times smaller than the animalcules seen by Swammerdam and named by him water-fleas or water-lice. ''We can easily conceive,'' says he, ''that in all rain-water which is collected from gutters in cisterns, and in all waters exposed to the air, animalcules can be found; for they may be carried thither by the particles of dust blown about by the winds.'' He declared that after boiling and hermetically sealing the water in a vessel the animalcules could not be found.[1, 2]

The report of this discovery of animalcules by Van Leeuwenhoek in 1676 created such a sensation that the Royal Society of England held several meetings during 1677 for the special purpose of confirming his claim. His discoveries had met with much opposition, especially that of animalcules in rain and other waters. He was considered illiterate, and for this reason his ability to discover anything worthy was regarded as unpromising.

The Royal Society on April 5, 1677, requested Nehemiah Grew to make experiments having as their aim the confirmation of the claim of Van Leeuwen-

hoek to the discovery of the animalcules in rain-water and pepper-water, and to report his findings to the society. On October 15, 1677, the Royal Society asked Robert Hooke to make investigations similar to those being conducted by Grew. Hooke and Grew having tried and been unable to see these animalcules with their microscopes, the Royal Society advised them to have microscopes constructed with a greater magnifying power and employ them in searching for the animalcules. However, Hooke made glass tubes of various sizes, "some not thicker than ten times that of a hair from the human head," and in these tubes he placed the suspected water. He imagined that these tubes would increase the magnifying power of the microscopes used by him and Grew and thus enable them to see the animalcules on that side of the glass tubing which was most distant from the lens of their microscopes. Hooke and Grew reported again to the Royal Society, November 1, 1677, their inability to find the organisms, whereupon they were again advised to prepare pepper-water, to have better microscopes made and to examine the pepper-water with them.[1]

Having heard of the many discussions at the several meetings of the Royal Society relative to his discoveries and of the doubt in the minds of some regarding the validity of his claims, Van Leeuwenhoek furnished witnesses who had seen what he had seen: two clergymen, one notary and eight other trustworthy persons who had seen the animalcules moving in pepper-water. One group of witnesses said there were ten thousand animalcules in a single drop; another claimed there were thirty thousand, and still another asserted there were forty-five thousand. The size of the drop was that of a grain of wheat.[1]

At a meeting of the Royal Society held a week later, November 8, 1677, Hooke reported that notwithstanding he and Grew had soaked pepper berries in water for two or three days and had examined this water with a more powerful microscope they could find no animalcules. Mr. Henshaw, vice-president of the Royal Society, who never doubted the claims made by Van Leeuwenhoek, said that "possibly as it was winter, it was not the right time to see these animalcules," and he added that he had an acquaintance who had been in Holland the previous summer who said Van Leeuwenhoek had demonstrated them to him. Despite Mr. Henshaw's statement Dr Wistler replied "that these imaginary beings were indeed nothing else than little grains of pepper floating in the water and not animalcules." Wistler's declaration was strongly opposed by Dr. Mapletoft, who affirmed that Van Leeuwenhoek had assured him that he had seen the animalcules alive as well as dead and that he had seen them dead in the pepper infusion soon after he had added vinegar. Hooke sided with Wistler in this dispute, and stated that he could find nothing but pepper in the pepper-water. Finally it was decided that Hooke procure a more powerful microscope, search for the animalcules and report at their next meeting.[1]

At the next meeting of the Royal Society held one week later (November 15, 1677), Hooke reported that after making pepper-water, with clear rain-water and a small quantity of pepper berries and allowing this mixture to stand nine or ten days, he could see a great number of animalcules swimming back and forth, each having the shape of an egg or a clear bubble. According to his calculation each animalcule was one hundred thousand times smaller than a mite. At this meeting, Hooke having demonstrated the animalcules to the satisfaction of every one, it was resolved that the truth of Van Leeuwenhoek's discovery be recorded, and that the names of all those who had witnessed the demonstration be likewise recorded.[1] Sir Christopher Wrenn was present at this demonstration. It was in the early part of the last quarter of the seventeenth century that the world was amazed at the discovery of a "new-world-of-innumerable-beings," differing in size, shape and movement, which were

beheld in a single drop of water by means of "an artificial eye" devised by a strong man endowed with marvelous industry. Up to this time the cheese-mite was the smallest animal in creation. Pasteur and Lister came two hundred years later.

Van Leeuwenhoek was much talked of, especially in England. His discoveries exercised the greatest influence upon the anatomy and physiology of this period. The scientific world, agitated concerning them, was anxious to examine the microscopes made by Van Leeuwenhoek and was curious to learn how he manufactured the lenses through which he was revealing a new world.

Van Leeuwenhoek was elected a member of the Royal Society in 1679 and a medal of the society was presented him. On the obverse side of this medal (Fig. 7) is seen a medallion of Van Leeuwenhoek. The translation of the Latin reads. "Ant. Leeuwenhoek, member of the Royal Society of England." On the reverse side illustrations are seen of a bee-hive, a plant and the City of Delft. The Latin inscription from Vergil may be translated: "His work was in little things, but not little in glory."

On November 23, 1681, at a meeting of the Royal Society, Mr. Henshaw said he surmised that the lenses used by Van Leeuwenhoek were ground in an unusual way, that Van Leeuwenhoek illuminated the objects he examined under his microscopes in a special way and that he had a room especially fitted up in which he conducted his investigations.[1]

Hooke remarked that the lenses constructed by Van Leeuwenhoek were only what he had said they were in his "Micrographia" (1665); "melted glass balls, whole or cut in halves and formed into a lens." Mr. Henshaw suggested that because of the newness and the greatness of the discoveries made by Van Leeuwenhoek he be requested to make known his methods not only of grinding and polishing his lenses but also of the construction and usage of his microscopes. When this request of Mr. Henshaw was presented to Van Leeuwenhoek he replied, "I agree with you." We shall see, however, that he had no intention of complying with this request. He kept his methods secret. When a question was asked that he did not care to answer, he did not reply. A letter from Thomas Molyneux, dated March 14, 1685, was read at the meeting of the Royal Society April 1, 1685, wherein he stated, "It was not possible to get one of Van Leeuwenhoek's microscopes for money." A letter of Huygens states that Van Leeuwenhoek would not allow the Landgrave of Hessen-Cassel to handle his microscopes, fearing they might be copied. Once a German came to Van Leeuwenhoek and asked if he would sell him a microscope. Van Leeuwenhoek anwered promptly, "Nein bei meinen Leben nicht." When he was asked why he made so many microscopes and would not sell any, he remained silent. Van Leeuwenhoek evidently did not wish all his technique to die with him, because he willed twenty-six microscopes to the Royal Society of England, but he appears to have been desirous of concealing during his life almost all that he knew pertaining to the construction of microscopes and their usage. In fact, he states in a letter to Henry Oldenberg, the secretary of the Royal Society, that he had microscopes of a greater magnifying power than those he was in the custom of exhibiting, which he kept for his own use to examine micro-organisms in water.[1] William Molyneux, astronomer and mathematician, a brother of Thomas Molyneux, writes in his "Dioptica Nova," published by B. Tooke at London in 1692:

> The Heer Leeuwenhoek of Delft in Holland has lately applied himself with great diligence to the use of microscopes: of which instrument he thinks he has a better kind than was ever yet known. When I visited this Gentleman at Delft he showed me several that indeed were very curious, but nothing more than what I had ordinarily seen before, being composed only of one single very minute glass-sphere or hemisphere placed between two very thin pierced

laminae or plates of brass, and the object was brought to its due distance before the glass by a fine screw: but, for his best sort, he begged our excuse in concealing them.

In 1747, twenty-four years after the death of Van Leeuwenhoek, his microscopes and other scientific effects were placed on sale. The catalogue for the sale was printed in Latin and Dutch by the city printer of Delft, Reinier Boitet. The following is a translation of an excerpt from this catalogue.

> The catalogue of the far-famed microscopes made with much trouble and expense during many years by the deceased Van Leeuwenhoek, and left by him, who during his noble life was a member of the Royal Society of England, will be sold on Monday, May 29, 1747, in the city of Delft, in the guild chamber of Saint Luke, in the morning from 10 to 12 and in the afternoon from 2.30 to 5.[1]

The frontispiece of this catalogue is an engraving of a cabinet for microscopes. Two children, one holding a microscope in the hand, are examining the microscopes. The catalogue also contains an engraved portrait of Van Leeuwenhoek. The microscopes listed are three gold, one hundred and forty-seven silver, five silver and copper and three hundred and seventy-five copper. On page 45 there is an inserted sheet containing the names of the purchasers and the amount paid for their purchases. Twelve pieces of apparatus (Fig. 8) are also listed, which were used for holding, in a fixed position, a glass tube partly filled with water and just large enough to contain a small eel. The tail of the animal was placed uppermost so that the circulation of the blood might be examined by a microscope attached to the upper part of this apparatus. Eight of these pieces were constructed of silver and four of copper. The returns from the sale of these microscopes amounted to seven hundred and thirty-three guldens and three stuivers. One gold microscope brought twenty-three guldens. A silver one sold for ten guldens. Those of copper brought fifteen stuivers to three guldens.[1] The value of a gulden to-day, with us, is about forty cents, and that of a stuiver about two cents.

Haaxman says:

> It appears that all those microscopes remained in our land [Holland] judging from the names of the buyers. The name of Dirk Haaxman appears very often on the list of purchasers. It is surprising there are not more of these microscopes in my family.

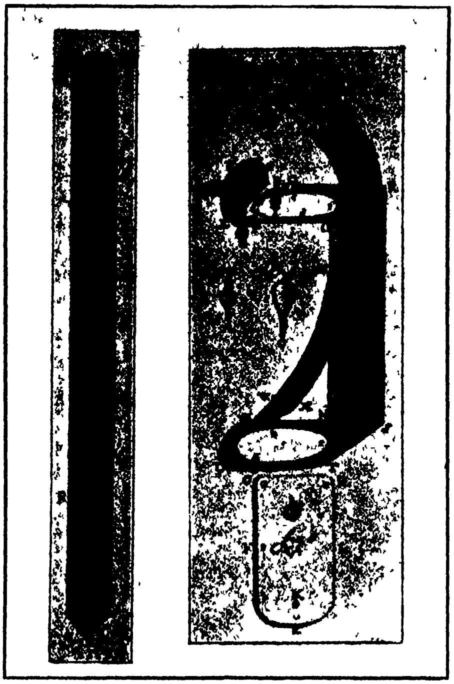
Haaxman also states that when a lad he examined insects with a microscope resembling one of those made by Van Leeuwenhoek, but attaching no more value to this instrument than to any other toy he lost it.[1]

On June 9, 1699, Van Leeuwenhoek wrote the Royal Society:

> Regarding my "glasses" [microscopes], I will not boast. I make them as well as is in my power. For many years the lenses have been made better and better and been better mounted. On the grinding and the mounting of a lens much depends. I have known those who ground lenses and who considered themselves competent to do so, but were not fitted for the work, because they could not tell an incorrectly ground lens from a correctly ground one. As one is able to discriminate between a good and a poor lens by so much is one able to fashion a perfect lens. And if one has made a perfect lens and tries to make new discoveries with it, one must not judge his discoveries at first sight, but must see them often. I have seen often. To brag, to make a noise about a thing is commonly called to see through a "glass" [magnifying glass]. When one looks through a "glass" [microscope] at first one may see one thing and later another thing, and when one investigates the findings they may be false. It is very easy for people, even those who are accustomed to look through "glasses" to be deceived, to be misled.[1]

Leibnitz and others urged Van Leeuwenhoek to establish a school in which students might be instructed in his methods of making lenses. He answered Leibnitz:

> I can see nothing coming from the establishing of a school in which young men might be taught the cutting and grinding of lenses. Many students have come to Leyden because of my discoveries and my method of making lenses. There is much in the making of lenses and the



—From E C van Leesum

FIG. 8. TUBE AND HOLDER

LEFT: A SMALL GLASS TUBE PARTLY FILLED WITH WATER WHICH WAS JUST LARGE ENOUGH TO HOLD A SMALL EEL. RIGHT: APPARATUS USED IN CLAMPING THE TUBE, SO THAT, WHEN THE MICROSCOPE (E–F G–H–I) WAS FASTENED TO ITS UPPER PART BY THE SCREW H THROUGH THE HOLE K IN THE MICROSCOPE, THE EYE MIGHT BE FIXED UPON THE LENS AT L AND THE TAIL OF THE EEL EXAMINED.

discovery by them of things concealed from our eyes, and because of this, most of these students propose to obtain money through science or through learning to become well known. It is plain to me that out of a thousand persons not one would be fitted to give himself to such study, because it takes much time and money, and in order to accomplish anything one's entire mind must be given up to the study.[1]

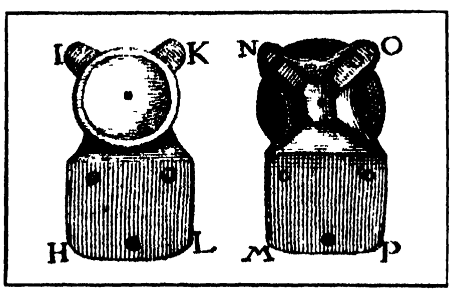
On March 13, 1716, he wrote Leibnitz:

> I have never had any desire to teach. If I instructed one I should have to instruct others or they would accuse me of partiality. I wish to remain free. I do not look for money from my work, inventions or discoveries; and I do not try to get anything out of them. And, further, to do good work one must study, spend money and go into the work with all one's soul, which is surely a work not attractive to most young people.[1]

In a communication to the Royal Society, November, 1677, Van Leeuwenhoek states he had received a letter from Professor Theodore Craanen, of Leyden, requesting him to show some of his discoveries to his nephew (Johan?) Ham, a medical student at the University of Leyden, and that he complied with this request. Van Leeuwenhoek continued:

> Ham visited me a second time, in August, 1677, when he brought me, in a glass vessel, the spermatic fluid of a man who had cohabited with an unhealthy woman. He said he found living "animalcules" with tails, in this fluid and that they lived only twenty-four hours. He thought the presence of the animalcules was caused by the decomposition of the fluid. Further, he noticed that when he gave the man turpentine internally these animalcules died.

Van Leeuwenhoek examined this fluid, which Ham brought him, confirmed Ham's discovery and made many researches on the healthy spermatic fluid of man and of a great number of animals and found what he called "little worms" or "spermatic animalcules." He studied their shape and movements and thought there were both male and female spermatic animalcules. He said that a line formed by one hundred of them would not be as thick as a hair, that fifty thousand of them would not cover a



—From R J. Petri

FIG. 9. A MICROSCOPE WITH A REFLECTOR

WHICH WAS MADE BY VAN LEEUWENHOEK. THE REFLECTOR SIDE IS ON THE LEFT; THE OBSERVER SIDE ON THE RIGHT. THE ALLEGORICAL FIGURE, INVESTIGATION, IN FIG. 10, IS HOLDING A MICROSCOPE SIMILAR TO THIS ONE.

grain of sand and that one could count more spermatic animalcules in the wood louse than there are men upon the surface of the earth. It is said that "the report of Ham's discovery to the Royal Society by Van Leeuwenhoek made so much noise that it was spoken of at the court of Charles II, who expressed a desire to see "these strange beings.""[1, 6]

It is not clear whether Ham, of Arnheim, or Nicolas Hartsoeker, another Hollander, was the first to discover the spermatozoon. Hartsoeker (1656–1725) was an astronomer and a natural philosopher. He made great discoveries, but his paradoxical mind caused him to stray from facts. He taught at Amsterdam, was honorary professor at Heidelberg and toward the end of his career accepted the chair of mathematics and philosophy at Düsseldorf. He had some highly eccentric metaphysical philosophical notions, and was of a singularly disputatious temper.

Hartsoeker in his "Extrait Critique" alludes to Van Leeuwenhoek as follows:

> Among a quantity of useless observations there are some that are good and serve the advancement of learning I have never been so surprised as when our author, whose ability is below the average, spoke as he did of globules in the blood and in milk, and my astonishment was great when I heard that well-known physicians and professors of philosophy and of medicine have cited him with praise respecting his beautiful discovery of the globules in the blood and have adopted his galimatias. I visited him three times. I went there the first time with the mayor of Rotterdam and my father about the end of 1672 or beginning of 1673, which visit he well remembered, as we shall see. The second visit I made alone, towards the end of 1679, on my return from Paris. This visit was made half in the street and half in his doorway. His actions toward me excited my enmity, because I objected to his ridiculous ideas on anatomy, to which he could not reply. How do you dissect a flea or a moth so as to draw the testicles from the body and open the testicles and take the spermatic fluid out so as to see that it is filled with little animals, the form of little eels, very long and very thin? What glasses do you use to make this anatomical demonstration? If the lens is small you have not enough light and if the lens is large it does not enlarge enough? What knives do you use; the sharpest and the finest would crush the structure quicker than open it? And following that, no doubt on account of my objections, he left me abruptly, saying he had work to attend to.[1]

Hartsoeker tells us that the third time he called upon Van Leeuwenhoek was in 1697 or 1698, twenty years after his second visit, and that he was accompanied by the mayor of Delft. Van Leeuwenhoek was prepared to receive his guests and to show them some of his discoveries. The mayor presented Hartsoeker to Van Leeuwenhoek, "on which Van Leeuwenhoek," says Hartsoeker, "viewing me with disdain, refused to show us anything, and it would not have taken much to have had him throw us out of the house."[1] Hartsoeker says of Van Leeuwenhoek:

> All that he has said and has repeated a thousand times are only just so many words, and as for his sketches demonstrating his observations, they mean nothing at all and are only a confused lot of drawings.[1]

The following is an extract of a letter from Van Leeuwenhoek to Leibnitz: "I well see that many learned men will accept neither my discoveries nor my ideas. Therefore I prefer, rather than dispute with them, to solace myself with the hope they may later accept them."[4]

Many were skeptical regarding the discovery of the spermatic animalcules; however, among those who were not was Leibnitz, who wrote Van Leeuwenhoek, September 28, 1715, that "the learned Vallisnieri of Padua" distrusted the discovery of Van Leeuwenhoek, but that he thought of writing concerning this discovery and that he would give Van Leeuwenhoek credit for his part in it. Van Leeuwenhoek answered: "We have a Dutch expression: 'one blond crow does not make a cold winter.' If Vallisnieri is against me there are those who are with me."[1]

On September 25, 1699, Van Leeuwenhoek wrote Grew, that

[6] K. Sprengel, and A. J. L. Jourdan, "Histoire de la Médecine," Paris, 1815.

FIG. 10. AN ALLEGORICAL FRONTISPIECE

BY PETER RABUS, IN THE SECOND VOLUME OF VAN LEEUWENHOEK'S WORK PUBLISHED IN 1695.

notwithstanding so few people believe so many animalcules can be obtained in so little fluid, which I know to be a fact, and which the Royal Society of England doubted at one time, I will not be offended by any one who may reject my views; and as sure as I was of having discovered animalcules in water, so sure am I about my discovery of spermatic animalcules in the spermatic fluid of man, birds and fishes. It will suffice me if I obtain credit only from you and other eminent and learned men.[1]

A detailed announcement of the discovery of the spermatic animalcules was made December 17, 1698, by Van Leeuwenhoek to the ex-mayor of Rotterdam, Harmen van Zoelen.[1]

Dr. Becker[1] in his "Närre Weisheit und Weise Narheit," 1682, says:

> Die Welt still steht,
> Und nicht umgeht,
> Wie recht die Gelehrten meynen;
> Ein jeder ist Seines Wurms vergewyzt,
> Copernicus des Seines,
> Und also Herr Leeuwenhoek des Seinen.

Malpighi and Van Leeuwenhoek might

be called the completers of Harvey's discovery, because Malpighi (1661) discovered the circulation of the blood in the capillaries (pulmonary capillaries of the frog),[3] and because Van Leeuwenhoek (1686) studied and described the circulation of the blood in the capillaries of the web of the frog's foot, of the fin of fishes, of the tail of the tadpole and eel, of the bat's wing and of the ears of young rabbits. Van Leeuwenhoek observed and proved the continuity of arteries and veins by means of the capillaries and said it was difficult to determine where the artery ended and the venous radicle began.[1] He says:

> If now we have been fortunate enough (for which we have longed so much, and diligently looked in vain for many years) to expose so clearly the circulation of the blood and its passing from the arteries into the veins in the aforesaid frogs and fishes, we shall not be satisfied with it, but we shall do our best to examine it also in other animals and if possible to discover it there also.[7]

The following is an extract from a letter of Van Leeuwenhoek to the Royal Society, July 10, 1696, relative to his discovery of the capillaries:

> I took several of the least sort and put them into my small tube (partly filled with water) so that they could but just go into it. [See Fig. 8.] When I fixed these small eels before the "glass" and fixed my eye upon the fin near the tail, I saw with greater admiration than ever I did in my life before, the circulation of the blood, and that in so many sundry places; so that if I should delineate the little space composed thereof, it would not seem credible to most men.[7]

Van Leeuwenhoek called the capillaries "very small arteries" or "very small veins" or "very little vessels." He saw that they had walls, which some observers doubted. He detected the erythrocytes passing along the lumen of the vessels in single file. He noted that the blood may flow rapidly or slowly in the capillaries, or that it may stop and then flow in the opposite direction; that cold and heat affected the flow, and he attempted to measure the velocity of the flow.[1, 5] He says:

> The motion of the blood in these tadpoles exceeds that in all the other small animals and fishes I have seen; and seeing this has been so recreating to me, that I do not believe all fountains, or waterworks, either natural or made by art, could have pleased my sight so well. And now at last I spied a small artery; that notwithstanding it is so small that I judge but one small globule of the blood could pass through it. . . . Yet what was most remarkable was to see the manifold small arteries that came forth from the great one, and which were spread into several branches, and turning came into one again, and were reunited, that at last they did pour out the blood again into the great vein; this last was a sight that would amaze any eyes, that were greedy for knowledge.[8]

He tells of the elastic reaction of arteries and how the expansion of the arterial wall travels distally along the arteries as the pressure is increased within them.[5] He writes of having seen the fibrillae and transverse striation of voluntary muscle; the muscle bundles in the ox's tongue; the vascular plexus surrounding the muscle fibers in the diaphragm of a lamb, and the arrangement of the muscle cells of the heart (rediscovered by Kolliker, 1863) which he called "concatenatio fibrarum."[5] He states that the optic nerve of the ox and the horse has no central canal, as the ancients thought, but is composed of filaments or juxtaposed canaliculi filled with globules; the shaking of the latter by the impression of light caused the transmission of impulses to the brain. His observations on the structure of the nervous system, which were his least exact, were reported to the Royal Society between 1674 and 1685. Later (1715) his idea of a nerve trunk had improved with observations, because he described the nerve sheath, the nerve fasciculi and

[7] E. C. Van Leesum, "Old Physiological Experiments," dedicated to the Ninth Congress of Physiologists at Gröningen, E. J. Brill, Leyden, 1913.

[8] J. C. Dalton, "Doctrine of the Circulation," H. C. Lea's Sons and Co., Philadelphia, 1884.

the nerve fibers, saying that the nerve fibers were so thin that more than one thousand of them could be found in a nerve trunk which had a diameter equivalent to the sum of the thickness of three hairs taken from the head.[5] He made transverse sections of nerves and of the spinal cord and remarked that the transverse sections of the medullated nerve fibers in these structures, which he mistook for tubules, consisted of a membrane (rediscovered by Schwann, 1838) containing a liquid, and that in the center of this liquid there was a central point (axon or dendron) or corpuscle as he called it.[5,6] He described the vascular structure of the pia mater and the blood vessels (vasa nervorum) in the nerve trunk.[6]. He studied the rods and cones in the retina,[9] the lamellated structure of the crystalline lens, which had been discovered already by Stenon,[5,6] and the fat globules in milk.[1] He saw globules in adipose tissue and thought he saw globules in the brain and cord.[5] He found living spermatozoa in the uterus and tubes of a bitch and asserted that they and not the spermatic fluid played the essential part in reproduction.[10]

In his communication to the Royal Society (1679) Van Leeuwenhoek states he had seen the dentinal tubules or canaliculi in the teeth of man, elephant, horse, pig and cow. His communication was accompanied by drawings of these tubules. He observed that the tubules ran from the interior of the tooth to its periphery; that processes of the pulp tissue (fibers of Tomes) ran into the tubules, and he thought these tubules were characteristic of dentin. He said that they could be seen only when highly magnified and that they had a diameter of 1/5,400 of the width of the thumb. It was not until 1835 that this work of Van Leeuwenhoek on the teeth was confirmed by Retzius and Purkinje.[11,12]

The dentinal tubules permit the passage of lymph, ink, oil, dyes, etc. Van Leeuwenhoek saw blood stains in the dentinal tubules as later did Felix Dujardin (1801–60), who saw blood stains in the dentinal tubules of persons who had died of cholera or who had been asphyxiated by carbon monoxide; the infiltration of the dentinal tubules by the decomposed blood reaching the dento-enamel junction of the tooth (the erythrocytes are too large to enter the tubules) gave the tooth a brownish-red color.[5]

Van Leeuwenhoek described the squamous epithelial cells of the epidermis, having found them in the cerumen of the ear and the sweat of the hands and face, and said they resembled fish scales and that they were replaced continually by new scales. He found squamous epithelial cells in the secretions of the mouth and vagina. He made comparative studies of normal epidermis, epidermis of cicatrices and keratosis, described the Negro's skin and said that the color of the skin depended upon the epidermis. He saw the epithelium of the intestines and gave an accurate description of hair.[5] He gave the name "filamenta seu stamina tenuia tendinum" to connective tissue.[9] He made microscopical studies of insects and their metamorphoses, of the parasites of man and animals, of the structures and germination of plants, of grain, of crystals and tophi. He discovered and studied the movements of the vinegar eel in vinegar and the vibrios (treponema microdentium and macrodentium?) in the tartar on teeth.[3] He found micro-organisms in the mouth and showed their presence to be greater in the "food rests" between the teeth than elsewhere.

[9] J. G. Bernard, "Histoire des Microscopes," Olher-Henry, Paris, 1886.

[10] A. Donné, "Cours de Microscopie," J. B. Baillière, Paris, 1844.

[11] Dictionnaire Universal d'Historie Naturelle, Fortin, Masson et Cie, Paris, 1843.

[12] Bayle et Thillaye, "Biographie Médicale par Ordre Chronologique," Adolphe Delahays, Paris, 1855.

Van Leeuwenhoek discovered (1680) minute globular or ovoid particles in fermenting fluids. This was the first observation of the yeast plant.[13] In 1837, both Schwann and Latour discovered the organic nature of yeast, and showed that the yeast-plant causes fermentation. He denied the then accepted theory that fermentation took place in the blood because he was unable to see air bubbles in the circulating blood.[6] He showed that weevils of granaries are grubs hatched from the eggs deposited by winged insects, and are not bred in and from wheat, as was then believed. He not only described the structure of the flea but also traced its entire history of metamorphoses from the egg. He even noted that the pupa of the flea was attacked and fed upon by a mite. He was the first to discover that the blighting of the young shoots of fruit trees was due to the aphids and not to the ants also found on the trees. He studied carefully the life history of ants. He made studies of the sea-mussel, fresh-water mussel and other shell-fish. He said they were not generated out of the mud or sand, but from spawn. He made careful studies of the ovum of the fresh-water mussel. He showed that eels were produced by the ordinary process of generation, and not from dew. He discovered rotifers, noted their resistance to drought and declared that the resistance was due to the impermeability of the casing in which they were enclosed, which prevented the evaporation of the body fluids. He described the different structures of the stem in monocotyledonous and dicotyledonous plants.[14] It is said that he was greatly pleased when a sailor brought him the eye of a whale, which became a source of many investigations.[3]

He relates, in a letter on July 10, 1696, to the mayor of Amsterdam, Nicolas Witsen, that he had made experiments pertaining to the movement of the earth and that he had discussed his results with Christian Huygens.[1] While examining an opaque object Van Leeuwenhoek used a mirror of polished copper to reflect the light upon it. In all probability Lieberkühn knew of the reflector devised by Van Leeuwenhoek when he constructed his own reflector of polished silver. Lieberkühn, however, is considered the inventor (1738) of the reflector for the microscope.[2, 9] In the allegorical frontispiece of Van Leeuwenhoek's work published in 1695, the central figure representing "Investigation" is seen holding a microscope, made by Van Leeuwenhoek, which is furnished with a reflector (Fig. 10). Petri in his work "Das Mikroskop"[15] has an illustration (Fig. 9), of a microscope with a reflector constructed by Van Leeuwenhoek similar to the one that "Investigation" is holding in the allegorical frontispiece (Fig. 10). Is not this reflector invented by Van Leeuwenhoek a forerunner of many medical instruments? Because Van Leeuwenhoek made contributions to botany, Robert Brown, the English botanist, named a species of plants of New Holland (the old name for Australia) "Leeuwenhoekia," and said: "In Memoriam, Antonii a Leeuwenhoek, micrographi celeberrimi, in cujus operibus plures et perpulchrae observationes de plantarum structura exstant."[1]

In a letter to the Royal Society Van Leeuwenhoek states that he had to kill more than one hundred mosquitoes in order to obtain one perfect proboscis for examination and that he was busy several days in obtaining this specimen.[1] And with reference to his investigations in general he says:

> On these said experiments I have spent more time than people will believe, but I have done them with pleasure. I have not noticed those

[13] J. C. McKendrick, "A Text Book of Physiology," Macmillan and Co., London, 1886.

[14] Encyclopaedia Britannica, thirteenth edition, *s. v.*, Leeuwenhoek.

[15] R. J. Petri, "Das Mikroskop," R. Schoetz, Berlin, 1896.

who said: Why go to so much trouble and for what use? I do not write for them, but only for those who have imagination, who are philosophically inclined and are able to appreciate what I write.[1]

. . . It is to be deplored that medicine is practiced by so many who use poor judgment. Where is the apothecary or surgeon who does not give laxative medicines in mild cases? And in many cases it is the only thing they can do, because most of them have no knowledge of how the body is constructed and they are not competent to question the patient to get at the cause of illness. And it is stated that there are physicians who visit patients and order remedies for them with the object of chasing money into the pockets of the apothecary.[1]

He opposed the method of purging, then in vogue, and said:

Such a powder is sooner a murder-powder than a healing-powder. Can we not call, with justness, that awful stuff which causes such movements of the stomach and intestines a murder-powder? We will take care that these murder-powders do not enter our body and that those who give them keep away from us.[1]

. . . It is strange that many people in our land believe so easily. Let but a "great doctor" come to the land, who announces himself as having made great cures, which he usually does, and come forward with many lies, then such quackery often finds not only an entrance with the common people, but it also goes over to those whom we expect to have better judgment. And when we speak to these quacks regarding their business of which they are supposed to have some knowledge, they are but ignoramuses. Some time ago there came into our land a great lying German, who claimed that by means of a powder which he called "sympathy" he could cure any ill. They brought this quack to my house in a carriage, so that I might admire him. His cure consisted of a powder to be placed in the urine of the patient. After I had listened to the man until he annoyed me, I asked the liberty to tell him my ideas. This was granted, and I told him that I did not believe such stuff and that I considered his cure an impossibility and that all those who had done this same thing before him were tricksters. He cited many cures which did not have a sign of truth, so much so that I was disconcerted by his ignorance, and told him that all who would traffic with him would be cheated. This proved true. Is it not miserable that our nation goes over to such people, when we can be served satisfactorily by our own physicians, our own compatriots, who possess a great many more gifts than the foreigner we have mentioned? We learn by experience that those who are most ignorant of the art and science of healing are those who make the most noise.[1]

Van Leeuwenhoek's opinion was considered so valuable that people came from foreign countries to consult him. Merchants, physicians, surgeons and corporations sought his advice. In 1656, the mayor of Amsterdam, Nicolas Witsen, who was also president of the East India Company, consulted him in behalf of this corporation. He was asked for something to kill the worms in the nutmeg. Van Leeuwenhoek advised that the places where the nutmegs were stored and the ships in which they were imported should be fumigated with sulphur.[1]

He thought many disorders arose from the blood being too thick, because it traveled so slowly through the capillaries, and that much drinking would thin the blood. He applied this theory to himself, so that whenever he had eaten much in the evening, he drank more and hotter coffee next morning, to encourage sweating, and he said "that having eaten so much, an entire apothecary shop would not help me as much as this simple remedy. I noticed that tea would make me sweat in the same way."[1]

Harting says that Van Leeuwenhoek was the first to possess a collection of microscopical specimens and that he excelled in preparing them. In a letter to Leibnitz of November 17, 1716, Van Leeuwenhoek relates: "I have shown two celebrated professors the dead spermatic animalcules which I placed in a thin glass tube twelve years ago, in which we could distinguish very plainly the body from the tail."

The following specimens prepared by Van Leeuwenhoek were advertised for sale in 1747:

Muscle fiber of a whale and of a codfish.

Cardiac muscle (goose). Transverse section of muscle of fish. Desquamated epithelium (skin) of man. Crystalline lens (ox). Erythrocytes (man). Liver (pig). Transverse section of wall of bladder. Bladder of ox. Papillae of tongue (ox). Hair of sheep, bear, beaver, deer. Hair from nose. Desquamated epithelium from the human tongue. Scales of perch. Spinning apparatus of spider. Threads of spider's web. Mandible of spider. Eyes of spider. Spinning apparatus of silk-worm Brain of fly. Optic nerve of fly. Foot of fly. Mandible of flea Foot of flea. Eye of beetle Skin of louse. Mandible of louse. Section of coral. Section of oyster shell. Transverse and longitudinal sections of elm, fir, ebony, linden, oak, cinnamon and cork trees. Sections of nutmeg and of bulrush. Grain of rye. Pieces of white-marble, rock-crystal, diamond, gold-leaf, silver and saltpeter.[1]

For nearly three quarters of a century this patient, industrious and ingenious man examined without order, method or any preconceived idea almost everything attracting his attention and made many discoveries, but his confidence in himself and his instruments also led him into errors and the making of strange assertions. It is said that Van Leeuwenhoek was opinionated and extremely vain and had many controversies.

In a letter to George Garden, of the Royal Society, Van Leeuwenhoek says:

My object is not to remain opinionated because of my own views, but as soon as any one shall give me probable reasons against my views which I can accept, I will abandon my own and go over to another's. And, this the more, because my investigations are made only with the object of discovering the truth, as much as is in my power, and to put the truth before the eyes of all; and with the little talent that I have to withdraw credulity from the world. I know well that my investigations are not coordinated, but that among them there are conflicting discoveries; and because of this I say again that my object is not to hold my opinions any longer than to that time when I would be better informed through my observations, from which it will follow that I will have to go over to other ideas which I will never be ashamed to do.[1]

Haaxman says: "An honest simple righteous character was Van Leeuwenhoek. The more one reads his letters the greater must he be esteemed."[1]

In another letter to George Garden he writes:

Regarding the differences of Swammerdam and De Graaf, I knew these men, they have been at my house many times and I admire their discoveries. And if they were still living they would be red with shame because of their squabbles, that were caused by each laying claim to the priority of having discovered certain organs of generation in the female.[1]

The members of the Royal Society who had long admired the discoveries of the ingenious Hollander were anxious to learn something of the man himself and of his instruments, so they sent Dr. Molyneux to visit him. He writes, February 16, 1865:

I found him a very polite man, very agreeable and really endowed with great natural aptitude, but contrary to my expectation totally illiterate. He is ignorant of Latin, French, English and all other languages except his own, which therefore impedes his reasoning. Not knowing in any way the ideas of others, he has in his own, such assurance that he attempts to explain things in an extravagant and fantastic manner.[1]

Many were envious of Van Leeuwenhoek, but he had many admirers, among them the Duke of Wurtemberg, the Duke of Brunswick, the Landgrave of Hessen-Cassel, Charles II, George I, Queen Anne of England, Frederick II of Poland, Frederick I of Prussia. When Charles III of Spain came to The Hague he delegated Prince Lichtenstein to invite Van Leeuwenhoek to come there and demonstrate some of his discoveries to him. The historian, Girard von Loon, gives the following account of the visit of Peter the Great to Van Leeuwenhoek in 1698:[1,3]

The Czar left The Hague in one of those yachts used on the canals, and arriving at Delft invited the celebrated Antony van Leeuwenhoek to call upon him and bring his incomparable microscopes. Van Leeuwenhoek then had the honor of showing his Imperial Majesty, among

other things, the circulation of the blood in the tail of the eel. This curious observation and others so pleased the Czar that he spent two hours with Van Leeuwenhoek and when he departed, he shook hands with him and thanked him.

Some of Van Leeuwenhoek's works, printed in Dutch, were published at Delft and Leyden, and in 1695 all his writings were gathered and published at Delft in four volumes entitled "Arcana natura ope et beneficio exquisitissimorum microscopiorum detecta, varisque experimentis demonstrata ab Antonio a Leeuwenhoek." Other editions appeared in 1696, 1697 and 1719, and in 1722 the four volumes were republished at Leyden with the title "Opera omnia, seu, Arcana naturae ope exactissimorum microscopiorum detecta, experimentis variis comprobata."[12]

The following is a translation of a description in Latin by Peter Rabus (1695) of the allegorical frontispiece (Fig. 10) in the second volume of Van Leeuwenhoek's work published in 1695:

The Specter of Philosophy, Queen of Science, standing behind the table, is disclosing Nature, formerly concealed but now revealed. Sagacious Investigation, upon whose temples are wings and who is clothed with a robe covered with eyes, has before her the different products of Nature which she is examining with a microscope made by Van Leeuwenhoek, in order to search out how the products are begotten and born. [This microscope is furnished with a reflector. See Fig. 9.] Standing behind Investigation, in the right background, is Diligence, always active Diligence is guiding Error. Error is represented as a poor one-legged man, whose eyes are bandaged and whose face is disfigured by the ears of an ass. Error is resisting Diligence. Three men are seen in the right foreground who pride themselves upon being philosophers: the first, (kneeling behind Investigation) a superstitious Jew; the second, (standing) a Christian, not less credulous, and the third (at left of the Christian), a Heathen, from the school of Aristotle who carries hidden qualities on his shoulders. The three have not been able to raise themselves to the place where stands Truth, who has no need of seduction and who is crushing horrent Envy under his feet. The Light Divine falls from Heaven and shines upon the microscope of Van Leeuwenhoek.

On November 20, 1719, Van Leeuwenhoek wrote the Royal Society:

I am about to enter my eighty-fifth year; my hands grow heavy and commence to tremble. In saying adieu to you I wish to thank you again for the honor you have done me in making me in 1679 a member of your illustrious society.[1]

Zeal for work continued with Van Leeuwenhoek to within thirty-six hours of his death, when he was found writing his report to the East India Company respecting the presence of gold in a specimen of sand which had been sent him by the president of this company for microscopical examination.[1]

The epitaph on the tomb of Van Leeuwenhoek in "The Old Church" or Church of Saint Hippolytus at Delft was written by his friend Huibert Cornelizoon Poot, "The Robert Burns of Holland."[1, 16] The translation of a part of it reads:

Here lies Antony Van Leeuwenhoek, oldest member of the Royal Society of England, born at the city of Delft the twenty-fourth of October, 1632, and died the twenty-sixth of August, 1723, having reached the age of ninety years, ten months and two days.

You, O wanderer, having respect for old age and wonderful talent, stand in veneration. Here gray science lies buried with Van Leeuwenhoek.

[16] "Description of the Principal Tombs in The Old Church at Delft," published by the Churchwardens, Delft, 1907.

THE TOPOGRAPHIC BASE MAP OF THE UNITED STATES

By J. G. STAACK

CHIEF TOPOGRAPHIC ENGINEER, U. S. GEOLOGICAL SURVEY

A MOTORIST has written, "Left to myself, I instantly reach for the left-hand door pocket, wherein resides a splendid assortment of maps. I spread one out, and instantly my mind passes into space. When the family appears, an hour later, I fold it up with a sigh of satisfaction. I have traveled far and made great plans for future voyaging."

Most maps are designed to present information of some particular kind. Railroad maps, highway maps, drainage maps, weather maps, air-navigation maps—all convey special information to the user. They are known as compiled maps, the particular information they are intended to convey being laid down on a base map, and they serve many very useful purposes.

However, these special information maps are simply two-dimension maps, picturing relative direction and distance. If a third dimension is added by means of contour lines to show elevation above sea-level they are converted into topographic maps, thus adding materially to their value and general utility. The most satisfactory method yet devised of representing relief is by means of contour lines. They were employed as early as 1728 by the Dutch engineer Cruquius to represent the bed of a stream, and a little later they were applied by Dupair-Triel on his map of France. A contour on the map represents a line on the ground, all points of which have the same elevation above the adopted datum, usually sea-level. Contour lines are drawn to represent regular intervals of elevation, which may range from one foot to 500 feet or more, depending on the nature of the country mapped and the size and scale of the map. The lines indicating steep slopes are crowded together; those indicating gradual slopes are far apart. In mountain areas they are numerous; in the plains they are few. In a region of rounded hills, they are smooth curves; in rough country they are angular and compact. Thus with a contour map in hand an experienced map reader visualizes at once and clearly the physical features of the country.

For the early development of topographic maps we are indebted largely to the military needs of nations. Inasmuch as a better understanding of the terrain for movement of armies was required than could be obtained from a two-dimension map, various methods by which the irregularities of the surface could be represented were employed. Thus we have early military maps representing relief by hachures, contour lines or shading. The fact that practically all European countries are at present covered by adequate and accurate topographic maps is the logical outgrowth of early military requirements. Indeed, in most countries of the present day topographic maps are made and published by their military departments. The United States, while recognizing the value of topographic maps in the national defense, utilizes them largely for the scientific study and inventory of its "tons of coal, barrels of oil and second-feet of water" and in the solution of the engineering, economic and industrial problems that affect the welfare of its people in which a knowledge of the "lay of the land" is vitally important.

In response to a report made by the National Academy of Sciences, Con-

gress created the U. S. Geological Survey in 1879 to coordinate under a permanent bureau the geographic and geologic surveys which at that time were being conducted in the public domain by four independent establishments. The new organization was charged with the duty of classifying the public lands and reporting on the geologic structure and mineral resources of the national domain.

To function properly as a scientific fact finder, the Geological Survey realized that a topographic base map which would accurately delineate physiographic and cultural details was a necessity. Accordingly, a plan was formulated and adopted to map the entire United States systematically in this way. The whole country was divided originally into quadrangular areas of one degree in latitude and longitude, to be mapped on the scale of 1: 250,000, or about four miles to the inch. At the present time a quadrangle measuring 15 minutes each way, mapped on the scale of 1: 62,500, or about one mile to the inch, is adopted as the standard unit for a general-utility base map of the greater portion of the country, except the mountainous and desert regions of the West, where a 30 minute quadrangle is the standard unit. Maps on these scales are being supplemented by base maps on the scale of 1: 31,680, or half a mile to the inch, in reclamation, industrial and metropolitan areas where larger maps are indispensable for intensive engineering and city-planning studies.

This general-utility map, sometimes called the master map of the entire country, is being engraved and printed in sheets about 20 by 16½ inches in size, suitable for easy handling and filing. An indication of its popularity is the fact that nearly a million copies of individual sheets were distributed last year to the general public, to other government bureaus and to state or municipal agencies.

The very latest surveying instruments and methods are utilized in making this topographic base map. To prepare it specialized talent is necessary, trained in representing ground forms accurately on paper through the medium of contour lines, which are actually drawn in the field by the engineer.

Although this topographic base was planned primarily to serve the needs of the geologist in his researches and studies of the mineral resources of the country, to aid the hydrologist to gather pertinent information on the flow and utility of streams, on the occurrence of ground water, on the quality of water supplies and on the water-power resources of the country, and to assist in the scientific classification of the public lands, this informative type of map serves very many useful purposes in engineering, scientific and industrial investigations carried on by other government bureaus, state and municipal agencies, business organizations and private individuals. In the succeeding paragraphs are set forth a few examples of concrete and beneficial applications of these maps in the solution of varied problems.

Topographic base maps afford the geologist a medium through which he can make the results of his field investigations usable by others. They help him to solve fundamental regional problems and to interpret broad structural conditions in areas where coal, oil and gas exist. They make his task much easier in the search for potash, phosphates, copper, lead, zinc or other ores or minerals essential to modern industry. It is estimated that a first-class topographic base map saves at least 60 per cent. of the geologic investigator's time in his field work. This is especially true where large-scale base maps are available for detailed studies of rock structure in mineralized areas.

A great saving in highway construction can be effected if the availability

and quality of road-building material are known. A trained geologist engaged in work on road material can, with the aid of a topographic base map, locate new and better deposits of gravel, limestone, shale, disintegrated granite, sand or clay. Such a survey can be conducted in 25 to 50 per cent. of the time necessary where a topographic base map is not available. This is particularly true in the locating of limestone and shale quarry sites. The geologist can spot on the map those places where the elevation and topography favor the development of a quarry. He can determine the feasibility of haul from the quarry site to the project on which the material is to be used. Or he can, as was exemplified near Superior, Wisconsin, concentrate the search for a desired type of gravel in the most favorable localities in wooded areas by identifying on the topographic base map the topographic forms that typify gravel deposits. Such a thorough study of available developed and undeveloped highway material has produced a saving in the State of Wisconsin's highway-construction program of $231,000 in 1928 and $212,000 in 1929 on 240 miles of paving.

To the angler, topographic base maps have very interesting uses in lake regions. In limnologic studies a knowledge of the area, depth and elevation above sea-level of lakes is desirable. These data combined with an analysis of the water determine the presence and the quantity of plankton, bottom forms and other material on which various species of fish feed. The presence or absence of fish food has a direct bearing on the abundance of fish in the lakes.

In the settlement of controversies over state and private boundaries or in the preservation and determination of old boundary lines topographic base maps assist the courts in dealing fairly. In very old communities, in which settlements and titles have developed without regard to surveys and many natural monuments upon which descriptions of boundary lines and titles to land depend have completely disappeared, accurate topographic base maps resulting from fundamental field surveys are the medium through which it is possible to redetermine boundaries to accord with recorded titles.

Local authorities of to-day find maps just as useful for purposes of taxation as they were in Babylonian times. The valuation officer is able to make a fairer estimate of the value of taxable property if he has at hand topographic data that show the location of the property in relation to other tracts of land and give him authentic information with respect to its elevation and drainage and its suitability for agricultural or other purposes.

A state or county government can well afford to postpone the solution of any drainage or irrigation problems until exact topographic information in the form of topographic base maps is available. Any attempt to plan a drainage and irrigation system without such a map would be mere guesswork and costly to the taxpayer. The greatest obstacle to the agricultural development of the Gulf coast and part of the Atlantic coastal section is the lack of natural drainage. The success of local drainage districts has been limited largely by failure to attack the drainage problem on a scale large enough to embrace a sufficient area—a whole county or a group of counties—because exact topographic data were not available in advance.

The economic value to highway engineering of accurate topographic information is illustrated in the final location of a highway from LaFollette to Jellico, Tennessee. The best preliminary trial survey possible had been made by the state highway department, resulting in the location of a road 26.3 miles long. Later a topographic base map of a belt of country between these two cities was made, and a new highway location with

no grade over 6 per cent. was worked out. The new location was 7.3 miles shorter than the other, which meant a saving of over $200,000 in construction costs, and there was an additional saving of $2,000 in making the final location by having at hand the base map to direct the field party. With the physiographic features correctly delineated on a map of the belt of country through which he desired to project his road the highway engineer was able to consider his problem in a broad way and, like the geologist, to solve with ease a fundamental regional problem in a mountainous country.

In railway location the topographic base map finds its primary value as a substitute for reconnaissance in preliminary surveys. Instead of the usual method of reconnaissance, a set of topographic base maps, if available, is obtained and enlarged to a workable scale, and a study is then made of the most feasible layout. Profiles are carefully prepared from the contour lines and intermediate elevations are interpolated with remarkable accuracy, so that estimates of necessary earthwork, culverts, bridges, etc., can be compiled.

The great value to a state of a complete set of base maps of its entire area will be increasingly evident from year to year The State of California has available a set of maps covering all the Sacramento River Valley and about 90 per cent. of the San Joaquin River Valley. During the past year the Division of Water Resources of the California Department of Public Works has carried on investigations at a great saving to the state with the aid of this set of maps, and recently it completed in a very short time the classification of the lands in these valleys. With the funds available a wholesale classification such as this could not have been made without the maps. They are indispensable and in constant use. In flood control, reclamation and river rectification they are the first maps to be consulted and generally furnish all the information necessary as to general location and carry the only available topographic information upon which to base preliminary studies.

In field investigations of the Public Health Service topographic base maps are of tremendous use in carrying on demonstrations of malaria control. They aid in laying out the most economical anti-malarial drainage schemes or in picking out the most advantageous places at which to carry on anti-mosquito investigations. Such work can be usually completed in a few weeks by the aid of these maps, whereas it is estimated that two years would have been required without them. In 1929 the Public Health Service was called upon to make a mosquito production survey of the eastern part of Massachusetts. Through the aid of topographic base maps the service was able to do its part of the work in less than a week. If these maps had not been available, one trained worker would have found it necessary to devote an entire season or else have failed in the work altogether. It is estimated that without the aid of such maps not more than one half of the area could have been successfully covered.

In planning studies of stream pollution and natural stream purification and interpreting the data obtained, topographic base maps are of great assistance. The value of such maps is appreciated where they are not available and less detailed and less reliable maps must be obtained from other sources. In the studies of existing sources of stream pollution affecting the public health they indicate the allocation of the population within and without the stream basins, the density of population per square mile in each drainage basin, the location and grouping of urban population having domestic sewage as the main source of pollution, the sections of the

basins which may be rural in character and in which pollution may be caused by surface drainage, the possible pollution from waste-producing industrial plants and the distances along water courses to sources of pollution. In the collection of hydrometric data for analyzing water from such streams, topographic base maps indicate the general topography in a drainage basin and give to the expert reliable data upon which to base an estimate of the rapidity with which run-off will occur from the different parts of the basin. The resulting surface erosion has a direct effect on the turbidity of the water and the chemical and bacteriologic analysis of samples. By the delineation of the swamps, ponds, lakes, reservoirs, etc., the maps assist materially in the interpretation of chemical and bacteriologic findings. Changes in the width of streams, the character of the stream banks and the flood plains, the position of waterfalls, dams, dikes, sluices and islands, the slopes of river beds and many other pertinent features are all represented by symbols on topographic base maps and are factors in the selection of points for collecting water samples for chemical and bacteriologic analysis. The maps indicate the location of railway and highway bridges from which samples may be collected, the proximity of communities and railroads to sampling points for shipping water samples and the location of probable sources of pollution above or below which sampling stations should be located.

Plant quarantine is established to protect the agricultural resources of the country and therefore affects the well-being of the whole people. In the recent campaign against the Mediterranean fruit fly in Florida, wherever topographic base maps were available (only about 8 per cent. of the state, or 4,700 square miles, has been adequately mapped) it was an easy matter to locate and plot the infested areas and plan prompt eradication measures. The U. S. Department of Agriculture in its plant quarantine and control administration has advantageously used topographic base maps. The accurate location of lakes, ponds, streams and highways, whether used or abandoned, and the representation of elevation by contour lines are particularly useful in its moth-control campaign during the spraying season. In mountainous and sparsely settled sections of the country certain methods of carrying on field work may be modified to conform to some peculiarity of the country as brought out on the map. In the campaign for the eradication of the pink boll worm the maps assist in locating canyons where plants related to cotton might grow and to trace out wind currents that carry the moth. Topography has a definite relation to temperature, wind and other climatic factors and to meteorologic conditions affecting the development and behavior of insects. Topographic base maps are used successfully in tracing the places where the Mexican bean beetle hibernates in the mountains at some distance from the bean fields. They are of great assistance in the study of bioclimatics, which relates to the general relation of climate to the distribution and abundance of insects. Bioclimatic areas can be readily outlined on topographic base maps without extensive field surveys. In the eradication of Texas fever among cattle topographic base maps have been invaluable in establishing a drift fence along the California-Mexico international boundary. Topography affects rainfall and other climatic conditions and thus has a bearing on the distribution and prevalence of various parasites of live stock, especially on the spread of eggs and larvae of parasitic worms. A good preliminary study of topographic conditions in infested areas can easily be made with the aid of these maps.

SOLID MATTER: WHAT IS IT, AND WHY?

By Dr. MAURICE L. HUGGINS
DEPARTMENT OF CHEMISTRY, STANFORD UNIVERSITY

SOLIDS differ chiefly in the kinds of atoms of which they are composed and in the arrangement of these atoms in space. A study of what solids are is largely a study of the nature of these arrangements and the properties of the different kinds of atoms when in such arrangements. A study of why solids are, and in particular why the particular arrangements of atoms which exist do exist, involves primarily the study of the structures of atoms and the nature and magnitude of the forces producing combination between atoms. I shall therefore begin this paper by mentioning those known facts about the structures of atoms which are of particular importance in connection with the problem under discussion.[1]

It is generally agreed now that all atoms are composed entirely of protons—relatively heavy positive electric charges, and electrons—relatively light negative charges. The protons are all concentrated, with some of the electrons, in the small nucleus in the center of the atom. Those electrons not in the nucleus are distributed among various shells around the nucleus. (The sort of motions they are describing need not be considered for our purpose; for simplicity we may treat them as if they were in definite fixed positions.) The electrons which are of primary importance in holding atoms together in molecules and in solids are those in the outermost, or valence shell. These electrons we call "valence electrons," and designate everything inside the valence shell by the word "kernel."

The kernels of atoms may be classified according to their charge, or in other words, according to the number of valence electrons with which they must be surrounded to produce neutral atoms. (Table I.) Thus helium, neon, argon and the other rare gases have kernels with no charge at all (and so they have no valence shells); atoms of the alkali metals all have kernels with one unit of positive charge; atoms of the alkaline

TABLE I

KERNEL CHARGES OF SOME OF THE ELEMENTS

Kernel Charge	0	1	2	3	4	5	6	7
		H						
	He	Li	Be	B	C	N	O	F
	Ne	Na	Mg	Al	Si	P	S	Cl
	A	K	Ca					
		Cu	Zn			As	Se	Br
	Kr	Rb	Sr					
		Ag	Cd			Sb	Te	I
	Xe	Cs	Ba					
		Au	Hg			Bi		
	Rn		Ra					

[1] For a fuller treatment see Lewis, *J. Am. Chem. Soc.* 38, 762 (1916); Lewis, "Valence and the Structure of Atoms and Molecules," Chemical Catalog Co., New York (1923); or Huggins, *J. Chem. Educ.* 3, 1110, 1254, 1426 (1926); 4, 73 (1927).

earths have doubly charged kernels; boron and aluminum kernels have three plus charges; carbon and silicon four; nitrogen and phosphorus five; oxygen and sulfur six and the halogens seven. Osmium, in osmium tetroxide, and ruthenium, in ruthenium tetroxide, probably have kernel charges of $^{+}8$.

A positively charged kernel attracts and sometimes holds valence electrons, the attraction being greater, in general, the greater the charge on the kernel. The magnitude of this attraction depends of course to some extent also on the size of the kernel, the distribution of electrons within it, the number and arrangement of other valence electrons around the kernel, etc.

Electrons in the valence shells of atoms, undoubtedly because each is spinning about its own axis and so is an elementary magnet, tend to pair off. Two single electrons in a valence shell seem to attract each other, but two pairs apparently mutually repel one another. This repulsion seems to limit the number of electron pairs which can be firmly held in an atomic valence shell. It is found that four pairs is the usual limit, although quite a number of cases of six- and eight-pair valence shells are also known, especially around kernels of small positive charge.

Although the tendencies of valence electrons to form pairs and of atomic kernels to be surrounded by stable valence shells—usually containing four electron pairs—are the major causes of combination between atoms, we should also bear in mind that even an atom in which these tendencies have been satisfied has some attraction between the positive parts of one atom and the negative parts of the other and in some cases as the result of the interaction of the magnetic fields surrounding each atom. These attractions, to which we may give the term "residual affinities" are often far from negligible.

Let us now consider the forces between like atoms, starting with those having a kernel charge of zero (the rare gases). It is evident that the only attractions between such atoms are the residual affinities just mentioned, and as these are weak, we should expect these elements to be gaseous except at very low temperatures. In the liquid state the residual affinities between the atoms are strong enough to hold them together within a small volume but not sufficient in magnitude nor sufficiently localized to maintain them in fixed positions relative to each other. On solidification we should expect the atoms to arrange themselves in some regular fashion with the atomic centers far apart relative to the size of the kernels. If so, the shape of the kernel should not be of much importance in determining the type arrangement, and it is therefore not surprising to find that the structure of solid argon[2], and xenon[3], as determined by X-rays, is that which would be assumed by any atoms of spherical symmetry—an arrangement in which each atom is surrounded by as many as possible (that is, twelve) of the other kind, commonly known as the cubic close-packed arrangements.

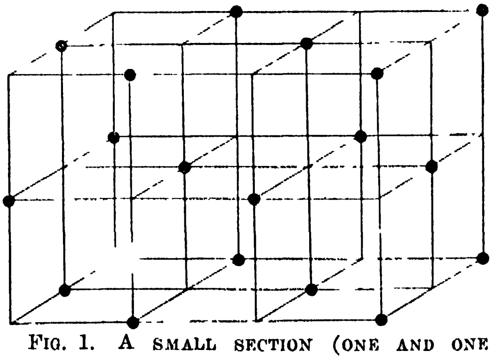


FIG. 1. A SMALL SECTION (ONE AND ONE HALF UNIT CUBES) OF THE FACE-CENTERED CUBIC OR CUBIC CLOSE-PACKED STRUCTURE. EACH ATOM IS EQUIDISTANT FROM 12 OTHERS.

[2] Except as otherwise indicated, crystal structures referred to are described in Int. Crit. Tables, I, pp. 338 *et seq.*

[3] Natta and Nasini, *Nature* 125, 457 (1930).

Fig. 1 shows the distribution of atomic centers in a small section of such a crystal. In the complete crystal, sections like this are set face-to-face, continuing the structure in all directions. The lines are of course only to aid in visualizing the spatial relationships. The "close-packed" nature of such an assemblage is most evident if one considers the arrangement of atoms in planes normal to the cube diagonal (Fig. 2).

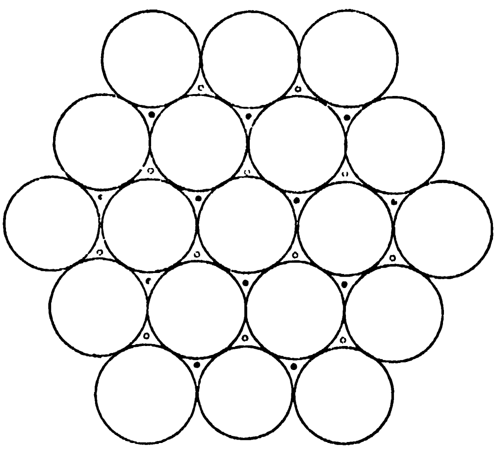


FIG. 2. REPRESENTING A LAYER OF SPHERES IN THE CLOSE-PACKED ARRANGEMENTS. THE CENTERS OF SPHERES IN THE SECOND LAYER ARE OVER THE FULL DOTS. THE SPHERES IN THE THIRD LAYER ARE OVER THE SMALL OPEN CIRCLES, IN CUBIC CLOSE-PACKING, OR OVER THE SPHERES IN THE FIRST LAYER, IN HEXAGONAL CLOSE-PACKING.

Atoms of the halogens have kernel charges of +7. The attraction for valence electrons is large, resulting in a strong tendency toward the formation of "complete" valence shells, containing four pairs of electrons. This tendency is satisfied, according to the theory of G. N. Lewis and according to the best experimental evidence, by the sharing of a pair of electrons between two atoms. (Fig. 3A.) In the halogen molecule thus formed the major tendencies of the atoms are satisfied, so the forces between molecules are relatively weak and the melting points and boiling points are

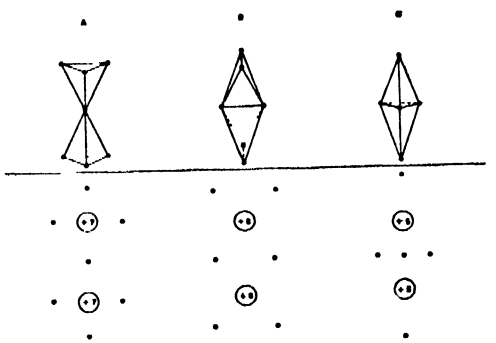


FIG. 3. ILLUSTRATING THE COMPLETION OF EIGHT-ELECTRON VALENCE SHELLS BY THE FORMATION OF SINGLE, DOUBLE AND TRIPLE BONDS, AS IN F_2, O_2 AND N_2. THE SMALL CIRCLES REPRESENT PAIRS OF VALENCE ELECTRONS.

low (compared with those of most of the other elements). Moreover, in iodine, the only one of the solid halogens whose crystal structure has been determined,[4] the atoms are in pairs and the distance between two atoms of a pair is less than that between two atoms in different pairs.

The oxygen kernel, with a net charge of +6, also exhibits a strong tendency to obtain 8-electron valence shells. This tendency can be satisfied by sharing two pairs of electrons between two atoms, thus forming a double bond. (Fig. 3B.) Similarly, nitrogen kernels with charges of +5, form N_2 molecules containing triple bonds. (Fig. 3C.) These O_2 and N_2 molecules do not have much attraction for each other, and we know that oxygen and nitrogen have low melting and boiling points.

Now it seems to be a general rule (first pointed out by Lewis[1]) that atoms of other than those in the first row of the periodic table do not readily form double or triple bonds. The tendencies of sulfur and selenium and tellurium atoms to obtain 8-electron valence shells can be satisfied however by the formation of rings, in which each atom shares electron-pairs with two others. Six-atom and

[4] Harris, Mack and Blake, *J. Am. Chem. Soc.* 30, 1583 (1928).

8-atom rings (Fig. 4) are possible without much distortion of the atoms or of the bonds between them, and such rings undoubtedly exist in sulfur vapor. The crystal structures of none of the forms of elementary sulfur have been completely worked out, but it is probable that in the ordinary forms there are molecular units of one or the other or both of these types.

In crystals of metallic selenium and tellurium X-ray studies[2] show that the atoms have satisfied their tendencies to

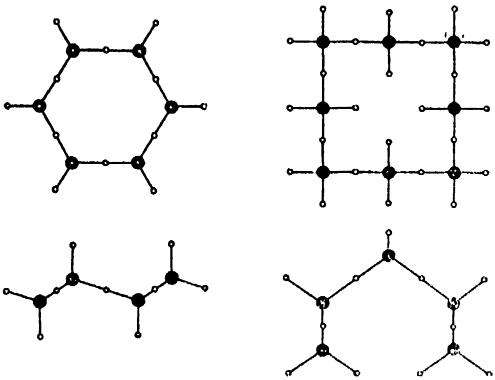


FIG. 4. 6-ATOM AND 8-ATOM RINGS, SUCH AS PROBABLY EXIST IN S_6 AND S_8 MOLECULES, SHOWN IN PLAN (UPPER FIGURES) AND IN ELEVATION (LOWER FIGURES). THE SMALL CIRCLES REPRESENT PAIRS OF VALENCE ELECTRONS. FOR SIMPLICITY THE STRUCTURES ARE DEPICTED AS THEY WOULD BE IF THE ATOMS WERE REGULAR (UNDISTORTED) TETRAHEDRA.

obtain 8-electron shells by forming spirals of atoms (Fig. 5) extending from one side of the crystal to the opposite side. Every atom (except those at the ends of the spirals) is bonded, by shared electron-pairs, to two other atoms in the same spiral. The distances between atoms in different spirals are relatively great and the forces between spirals relatively weak. These spirals furnish an example of what Lewis has called "continuing molecules," the size of which is limited only by the size of the crystal.

Phosphorus, arsenic, antimony and

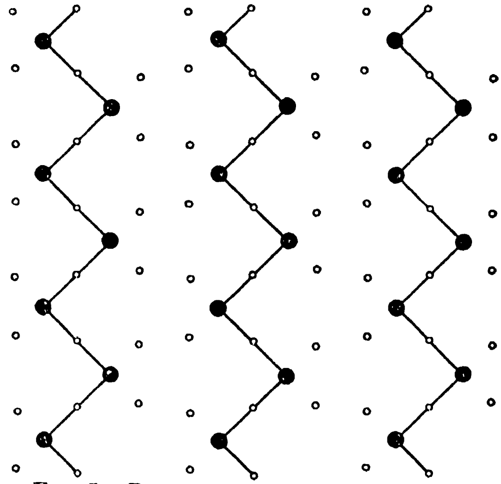


FIG. 5. REPRESENTING A TWO-DIMENSIONAL STRUCTURE ANALOGOUS TO THE STRUCTURE OF Se AND Te CRYSTALS.

bismuth, like nitrogen, have kernels, with net charges of $^{+}5$. The first three of these form 4-atom molecules, probably having structures such as represented in Fig. 6, with only single bonds between the atoms.[5] These elements all also

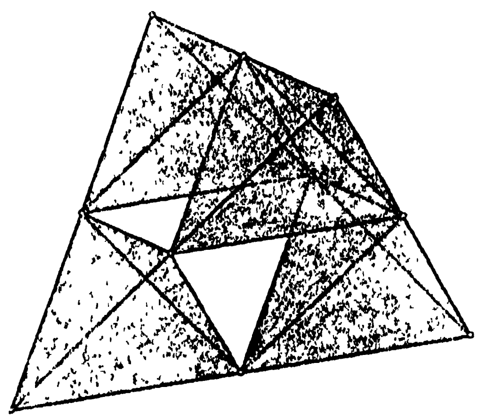


FIG. 6. THE PROBABLE STRUCTURE OF THE MOLECULES OF P_4, As_4, Sb_4 AND C_4^{----}. FOR SIMPLICITY THE ATOMIC VALENCE SHELLS ARE REPRESENTED AS REGULAR TETRAHEDRA.

[5] A tetrahedral arrangement of atomic centers has been found for the C_4^{----} ion in calcium carbide, Ca_2C_4, by Dehlinger and Glocker, *Z. Krist.* 64, 296 (1926). Moreover, white phosphorus, which gives P_4 molecules on dissolving or vaporizing, forms cubic crystals, as might be expected of tetrahedral molecules.

form[2] continuing molecules in which the atoms are in layers, with each atom bonded by single bonds to three others within the same layer (Fig. 7). The

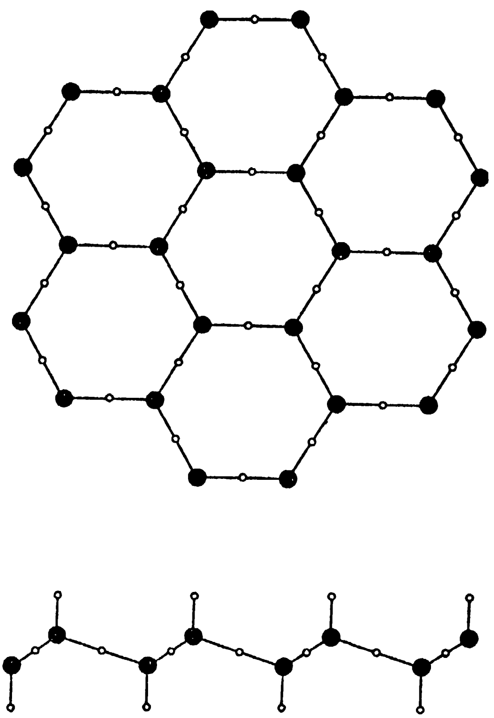


FIG. 7. A LAYER OF THE STRUCTURE OF THE RHOMBOHEDRAL FORMS OF P, As, Sb, AND Bi, SHOWN IN PLAN AND ELEVATION.

atoms within each layer are tightly bonded together, while the layers are held together only by much weaker residual forces.

Atoms such as those of carbon, silicon, germanium and tin, with kernel charges of $^{+}4$, can obtain stable valence shells consisting of four electron-pairs at tetrahedron corners (in the absence of other kinds of atoms) only by forming three-dimensional continuing molecules such as that in the diamond crystal[2] (Fig. 8). Each atom throughout the crystal is bonded to four others.

Such 8-electron valence shells are not possible when all the atoms have kernel charges of three or less, for the number

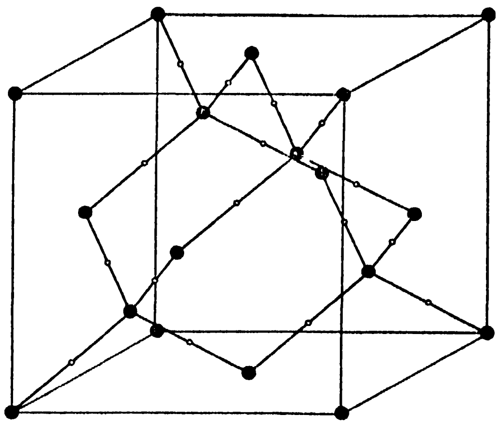


FIG. 8. THE UNIT CUBE OF THE DIAMOND CRYSTAL.

of electrons required to balance such charges is insufficient With kernels having such small charges the attractions for valence electrons are relatively weak. The distances from atomic centers to valence electrons, and also those between adjacent atomic centers, are relatively large, and the arrangements usually assumed are the "close-packed" arrangements—in which each kernel is surrounded by twelve others (Fig. 2). In a number of instances, probably to give a more stable equilibrium distribu-

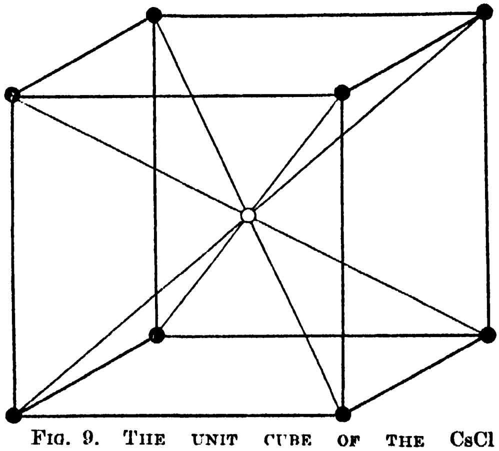


FIG. 9. THE UNIT CUBE OF THE CsCl STRUCTURE. THE CENTERED-CUBIC ARRANGEMENT, FOUND FOR A NUMBER OF METALS, IS SIMILAR, EXCEPT THAT ALL THE ATOMS ARE ALIKE.

tion of the valence electrons, the centered-cubic arrangement (Fig. 9), in which each kernel is surrounded by eight others, is found. The best evidence indicates that the valence electrons are in oscillation or rotation about equilibrium positions between the kernels, with several kernels around each electron and several electrons around each kernel. Whether or not these electrons are paired is still a moot question.

Let us consider now the structures of crystals of compounds. If all the atoms can obtain complete valence shells by sharing electron pairs between them, forming small molecules, such as CCl_4, SnI_4 and CO_2, the forces between these molecules will be quite weak, and liquid and crystal formation should take place only at relatively low temperatures. We should expect such molecules to persist as definite entities within the crystal, and that is found to be the case.[2] The exact distribution of molecules in the solid depends of course on the nature of the distribution of the residual forces between them.

Atoms with the larger kernel charges (6 or 7) sometimes completely remove electrons from atoms with small kernel charge (1 or 2), thereby producing ions. Each ion so formed has an attraction for ions of opposite charge. As a result of this attraction and of the mutual repulsion between like-charged ions, the ions come together in solid arrangements such as those of cesium chloride[2] (Fig. 9) and sodium chloride[2] (Fig. 10). In the former each ion is surrounded by eight of the other kind and in the latter by six. The cesium chloride structure is the one one would expect of ions of the same size having spherical symmetry or of non-spherical ions small in size compared with the distance between them; the existence of the sodium chloride type in which like ions form a close-packed assemblage, can be attributed to a considerable difference in size.

A still greater difference in size may be the chief factor producing the structure of Fig. 11 for cuprous chloride,[1] CuCl, and many other compounds, but it may also be that there is a definite tendency for the cuprous kernel—like many kernels of greater positive charge —to be surrounded by four-pair valence shells. This arrangement is like the diamond arrangement (Fig. 8) except that there are two kinds of atoms and that the valence pairs are much more tightly held by the chlorine kernels (charge $^{+}7$) than by the copper kernels (charge $^{+}1$).

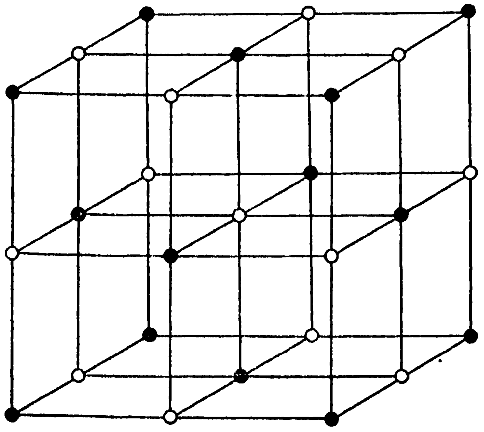


FIG. 10. THE UNIT CUBE OF THE NaCl ARRANGEMENT.

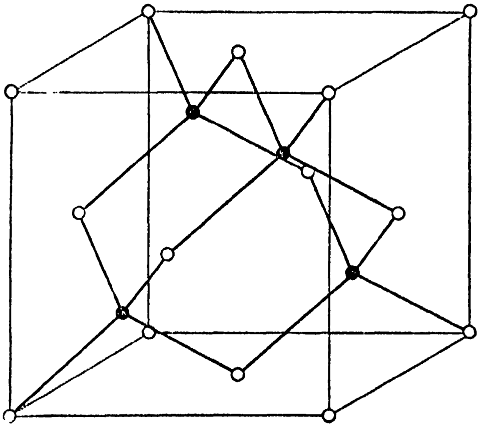


FIG. 11. THE UNIT CUBE OF THE STRUCTURE OF CuCl, ZnS AND MANY OTHER COMPOUNDS. FOR GREATEST STABILITY ONE WOULD EXPECT THE VALENCE ELECTRON PAIRS TO BE ON THE ATOMIC CENTERLINES, BUT MORE TIGHTLY BOUND TO THE Cl OR S THAN TO THE Cu OR Zn.

Ammonium chloride, NH_4Cl, has two different forms of structure.[2] The one stable at higher temperatures has a distribution of ions like that in sodium chloride. That stable at lower temperatures has the cesium chloride type of structure. In both forms each nitrogen is surrounded tetrahedrally by four hydrogens. The low temperature form is particularly interesting in that each hydrogen is probably on a nitrogen-chlorine centerline, and may be considered to be bonded to both by means of valence electron-pairs. (See Fig. 12.)

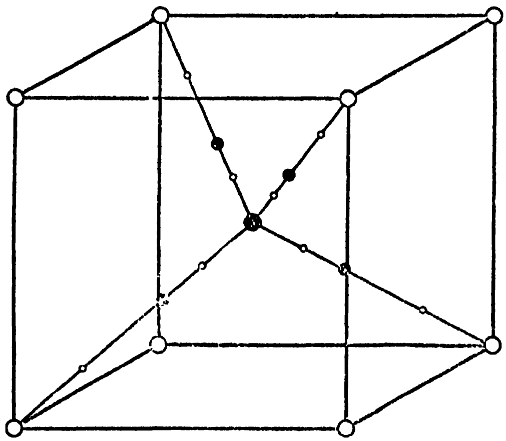


FIG. 12. THE UNIT CUBE OF THE LOW-TEMPERATURE FORM OF NH_4Cl. THE TETRAHEDRA OF VALENCE ELECTRON PAIRS AND OF HYDROGEN NUCLEI (THE SMALLER FULL DOTS) ARE ORIENTED AROUND THE NITROGEN AND CHLORINE KERNELS (THE LARGE FULL DOTS AND OPEN CIRCLES) IN SUCH A WAY AS TO GIVE GREATEST ELECTROSTATIC STABILITY.

Crystals of any of the compounds mentioned above can be pictured as being formed either from ions or from neutral molecules. The molecules, though neutral when considered as a whole, would be *"polar,"* the more electropositive atoms (those with small kernel charge) having but one or two electron-pairs in their valence shells and the more electronegative atoms (those with large kernel charge) having one or more valence pairs which are not acting as bonds between atoms. The attraction between the kernels of the positive atoms and the lone pairs in the negative atoms, or, more generally, the tendency of each electropositive atom to be surrounded by electronegative atoms, and *vice versa*, causes the molecules to come together in the arrangements described.

Applying these ideas to the structure of ice, we see a reason for the structure[6] deduced from X-ray data. The molecule we may represent as $\mathrm{H}:\underset{\ddot{\mathrm{H}}}{\ddot{\mathrm{O}}}:$. The attractions between the hydrogen kernels and the "lone pairs" in the oxygen

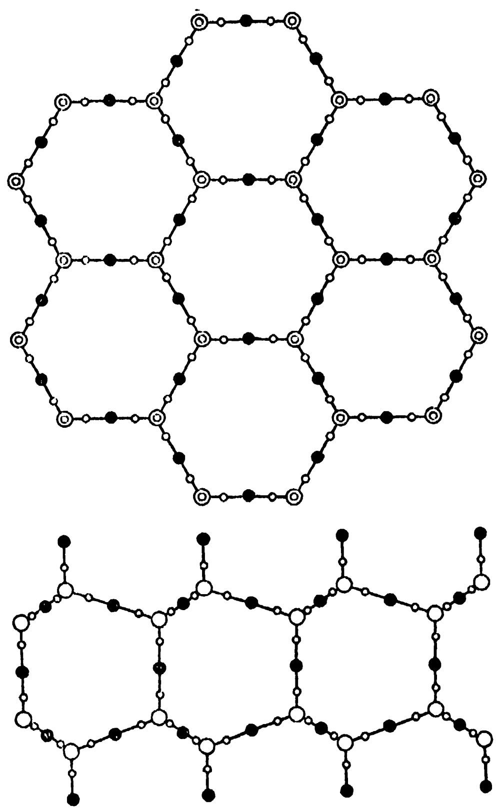


FIG. 13. THE STRUCTURE OF ICE, SHOWN IN PLAN AND ELEVATION. FULL DOTS DENOTE THE POSITIONS OF THE HYDROGEN ATOMS, LARGE OPEN CIRCLES OXYGEN, SMALL CIRCLES VALENCE ELECTRON PAIRS.

[6] W. H. Bragg, *Proc. Phys. Soc.* 34, 98 (1922). Barnes, *Proc. Roy. Soc.* A125, 670 (1929).

valence shells cause these molecules to aline themselves in such a way as to surround each oxygen tetrahedrally by four hydrogens, each of the hydrogens being midway between two oxygens. (Fig. 13.)

Another example is that of mercuric iodide,[7] : $\ddot{\mathrm{I}}$: Hg : $\ddot{\mathrm{I}}$:, which crystallizes in "layer molecules" in which each mercury is bonded tetrahedrally to four iodine atoms and each iodine to two mercury atoms. (Fig. 14.)

In ordinary quartz[8] it is found similarly that each silicon is bonded to four oxygens and each oxygen to two silicons, the whole crystal in this case being a single molecule. That both silicon and oxygen kernels (with four and six plus charges respectively) hold very tightly to the valence pairs between them is evidenced by the insolubility, high melting point and hardness of the substance.

Up to this point I have discussed only the arrangement of atoms in certain molecules and in perfect crystals. I wish now to mention certain types of irregularity, with their causes and effects.

Some crystals posses such a structure that it is fairly easy for slipping to occur between adjacent planes of atoms in certain directions (*e.g.*, between the layers of atoms in the close-packed arrangements, Fig. 2), the relative arrangement of the atoms on both sides of the "slip plane" or "glide plane" being the same before the slip as after. This can not of course occur if the shift involves any breaking and remaking of tight bonds. If the forces between the layers which are slipping past each other are not strong enough to hold them together, or in the absence of slipping, if the forces between two adjacent layers are sufficiently weak, the plane between them is a cleavage plane. In some cases, as in the "layer molecule" crystals, I have mentioned—phosphorus, arsenic, antimony, bismuth, mercuric iodide—cleavage is very easy to bring about. In single crystals of the metals, glide planes or cleavage planes or both are the rule rather than the exception.

In the growth of a crystal there are sometimes two or more ways in which an atom can add to the crystal surface which satisfy equally well (or nearly so) the forces between it and other atoms. For instance, imagine a crystal of a metal in process of formation. (See Fig. 2.) After two layers have been

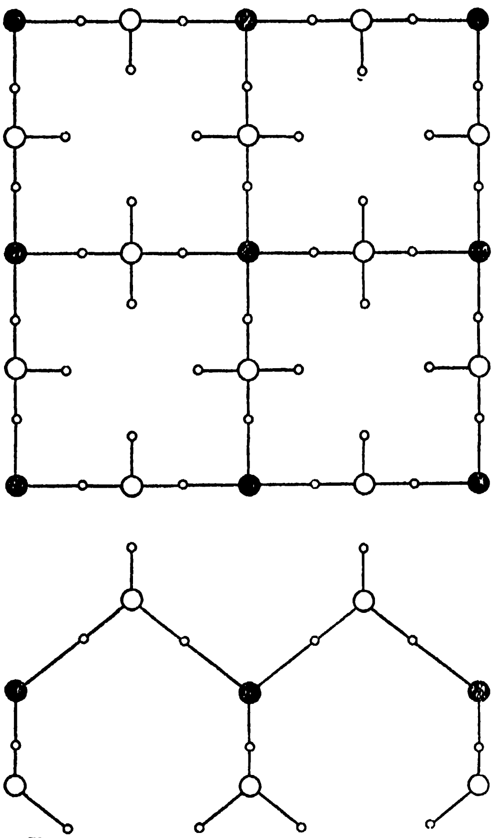


FIG. 14. THE STRUCTURE OF A LAYER OF ATOMS IN THE HgI_2 CRYSTAL, REPRESENTED BY PLAN AND ELEVATION. LARGE DOTS DENOTE Hg CENTERS, LARGE OPEN CIRCLES I CENTERS.

[7] Huggins and Magill, *J. Am. Chem. Soc.* 49, 2357 (1927). Bijvoet, Claassen and Karssen, *Proc. Roy. Acad. Sci.* Amsterdam 29; 529 (1926).

[8] Huggins, *Phys. Rev.* 19, 363 (1922). Lewis, "Valence, etc.", Ref. 1, p. 94. W. H. Bragg, *J. Soc. Glass Technology* 9, 272 (1925). Gibbs, *Proc. Roy. Soc.* A110, 443 (1926).

formed, the atoms in the third layer might place themselves either directly over those in the first layer or over the holes between the atoms in the first two layers. If the former, and the process is continued indefinitely, the atoms in each layer being directly over those in the second layer underneath, a crystal having the "hexagonal close-packed" structure results. If the layers are added so that the fourth layer is over the 1st, the 5th over the 2nd, the 6th over the 3rd, etc., the "cubic close-packed" structure is produced. If a crystal starts to be cubic-close-packed and then one layer "goes wrong," the subsequent layers however following the original scheme, a "twinned" crystal results, the whole crystal being symmetrical about the plane of twinning.

Another example of twinning (in a hypothetical two-dimensional crystal) is illustrated by Fig. 15. Imagine a two-

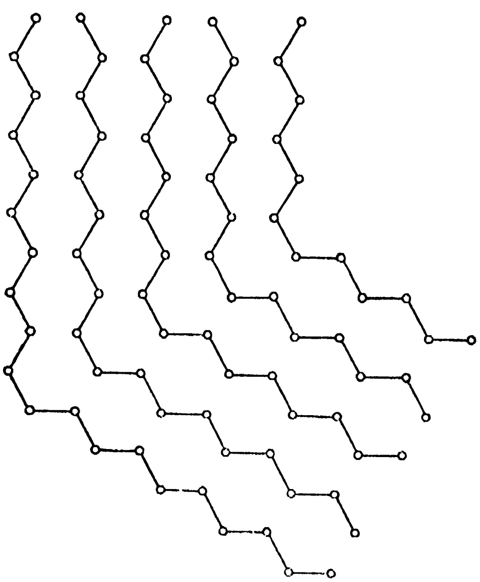


FIG. 15. ILLUSTRATING TWINNING IN A HYPOTHETICAL TWO-DIMENSIONAL STRUCTURE.

dimensional crystal growing regularly in the vertical direction. One of the atoms happens to add in the wrong place, all the primary valence forces and most of the residual affinities being quite as well satisfied as if this atom had gone where it really belonged. This out-of-place atom causes others (all in a certain row) to take up irregular positions. If the crystal then grows regularly again, a twinned structure such as that shown is produced.

In an ordinary metal there is a great deal of twinning. In fact the arrangement is probably usually more nearly like what we would get if we dumped a large number of shot into a box. Wherever there is twinning, however, any cleavage planes or glide planes not parallel to the twinning plane must come to an end at that plane. Hence gliding and fracture are much harder to produce in ordinary pieces of metal than in single crystals—that is, the latter are "softer." Gliding and cleavage can also be hindered to a large extent by the presence of small amounts of certain impurities, the added atoms serving to make the crystal planes irregular and to lock adjacent planes together.

Glasses differ from crystals in that there is no regularity throughout in the whole mass—although each electropositive atom is probably surrounded by electronegative atoms and *vice versa*. They differ from liquids in that each atom seems to be held by quite rigid constraints in or near a definite position of equilibrium. Being essentially different from both the crystalline and the liquid state (and also the gaseous state, of course), perhaps we should call the glassy state a "fourth state of matter."[9]

I wish to close with a brief consideration of the nature of wood. We all know that wood consists largely of cellulose fibers, between which and within which are water, resins and various organic and inorganic materials. The structure of cellulose has been the subject of speculation and research for many years, but

[9] *Cf.* Parks and Huffman, *Science*, 64, 363 (1926).

it is only recently that anything like a satisfactory solution has been attained. Studies[10] of cellulose by X-ray means show that the structure is one containing long string molecules (Fig. 16), the atoms in each string all being held together by primary valences. In this figure, the carbon atoms are represented by black dots, the oxygen atoms by circles. Hydrogens are not shown, but are attached to each oxygen except those in the rings and to each carbon not otherwise bonded to four atoms. Such a structure, although possibly incorrect in some details, accounts well for the physical properties of cellulose, its swelling—due to absorption of water—in directions perpendicular to the fiber axis, its chemical properties, etc.

Although it has not been possible to go very deeply into the subject in this paper, perhaps enough has been presented to give an idea of the sort of information which is being obtained nowadays in regard to the nature of matter and to give an indication of the marvelous results which are sure to follow further application of X-ray and similar methods to the study of such problems.

[10] Sponsler and Dore, "Fourth Colloid Symposium Monograph," Chem. Cat. Co., New York (1926), p. 172; *J. Am. Chem. Soc.* 50, 1940 (1928). Herzog, *J. Phys. Chem.* 30, 457, (1926).

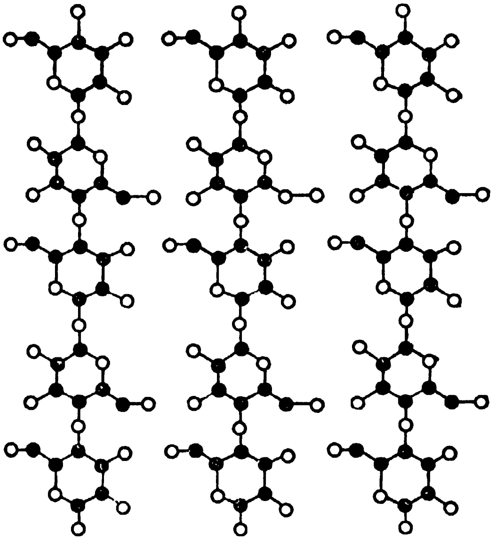


FIG. 16 REPRESENTING THE STRUCTURE OF CELLULOSE.

SOME OBSERVATIONS ON BUTTERFLY MIGRATIONS

By AUSTIN H. CLARK

U. S. NATIONAL MUSEUM

GREAT multitudes of butterflies flying steadily onward in a definite direction after the fashion of the flocks of birds which with us pass south in autumn and return in spring, have often been reported. Indeed, in many regions these mass movements of the butterflies are so very striking that no one can fail to notice them.

The term migration commonly applied to these linear group movements of the butterflies is a rather unfortunate one, as it implies a comparison with the migrations of birds, with which they have little in common except that they are movements measurable in geographical terms.

Bird migrations are typically movements of a very definite nature from the breeding grounds to another region more or less remote and back again, usually by the same path. In the case of birds the round trip is completed several or many times in the life of each of the individuals, and furthermore the movement usually involves all the individuals of a species in a given breeding area.

Butterfly migrations rarely involve more than a portion, and often only a relatively small portion, of the individuals in any given region. So far as the individuals are concerned, the migrations are in one direction only, and so far as the species is concerned, there is seldom any definite indication of a return movement.

There are also other differences between the migrations of birds and the so-called migrations of butterflies—but there are also some curious correspondences.

The problem of the so-called migrations of butterflies is a very complex one involving a great number of diverse factors, both external and internal. The internal factors vary more or less widely not only in the different groups of butterflies but also in closely related species within small groups, and in seasonal or other alternative forms within a species. The nature and relative importance of the external factors vary with the differences in the habits and reactions of the different species, and of the forms within a species.

In some butterflies migration is a regularly recurrent, usually annual, phenomenon, while in others it takes place only occasionally. In some it is more or less characteristic of certain forms within a species but never occurs in an alternative form.

It is probable that many butterflies not usually so regarded are in reality migratory, traveling always as independent individuals and chiefly at night.

Most migratory movements among the butterflies seem to be traceable to three main causes—first, the natural propensity of a gregarious species to wander; second, the inability of the males of certain species to live together if their number in a given area exceeds a more or less definite maximum, and third, the destruction of the food plant, or some other adverse circumstance affecting a more or less extensive region.

Observations made within the past few years in and near the District of Columbia seem to have a definite bearing on the origin of the migratory movements of certain types of butterflies.

The milkweed butterfly (*Danais*

plexippus) is normally not very common in this region at the present time, six or eight, perhaps as many as a dozen but seldom more, being seen in a large field at the end of the season. It was unusually scarce in the dry summer of 1930. On September 15 in the extensive meadows west of Cabin John only four or five were to be found.

On September 16 there was a heavy shower in the afternoon. On September 17 these butterflies had enormously increased in numbers, and those present in the meadows were without exception quite fresh; furthermore, by far the greater part of those captured were males. A visit on the following day showed this insect to be still more numerous, outnumbering all the other kinds of butterflies combined, while of those captured a slight majority were fresh females.

The appearance of great numbers of butterflies after a rain is a common and striking phenomenon in the tropics, where I have observed it in Venezuela, but it is not often noticed so far north as Washington. The name "storm fritillary" sometimes applied to this butterfly in the country may refer to its sudden increase in numbers after heavy rains.

On September 17—the day of their first appearance in large numbers—the individual butterflies were more or less evenly distributed over the fields, feeding everywhere on the goldenrod and also on the few and widely scattered thistles. On the next day (September 18) conditions were about the same, but sometimes as many as four or five would be seen about a single thistle.

On the succeeding day (September 19) it was noticed that the butterflies had to a certain extent become gregarious. They were no longer evenly distributed over the fields, but were to be found in more or less widely separated areas where, for instance, from half a dozen to a dozen would be feeding on the goldenrod in a space ten or fifteen feet square, or from six to ten would be seated on the heads of a large thistle with others on the nearby goldenrod. While in places two or three could be taken in a single sweep of the net, there would be none on the goldenrod for two hundred feet or more between the little companies of well-separated individuals.

These little companies were constantly on the move. But they always moved as individual butterflies and never as if the company were a unit. A butterfly would start up and fly for perhaps fifty or a hundred yards, finally settling on a goldenrod some distance—five or ten feet perhaps—from another individual. Then a third would settle near these two, and pretty soon another little company would be formed. Sometimes on being frightened a whole company would move off in the same general direction, but the individuals always seemed to scatter more or less. The procedure seemed to be, for the most part at least, a continuous forming, breaking up and reforming of small and loose aggregations of independent individuals But it was noticeable that the majority of the butterflies would keep within a certain area which was continually shifting north or south along the belt in which the goldenrod was most luxuriant.

While most of the butterflies flew only a foot or so above the tops of the goldenrod, one was seen to drop from a great height, being first observed on the downward path about a hundred feet above the ground.

On the following day (September 20) further changes had taken place. As we reached the field at half past two in the afternoon we saw, within a few minutes' time, four butterflies from twenty to one hundred feet or more above the ground headed southward but drifting westward toward Great Falls

before a moderate wind. Some minutes later a butterfly which rose five or six feet away and which could not have been much frightened mounted high into the air and departed in the direction of Great Falls. These traveling butterflies were seen in the western end of the field, where the goldenrod is stunted and scattered and is not visited by the butterflies.

In the more luxuriant portion of the fields the insects were more restless than they had previously been. They wandered about more and did not remain so long on the flowers. Also their numbers had decreased considerably. Most of them were now gathered into two flocks, a small one of two dozen or so individuals in the northern half of the field and a very much larger one in the southern half. Both flocks were more compact than any which we had seen previously, and as many as four butterflies were often to be seen on a single goldenrod.

The restlessness of the individuals in both flocks was quite apparent, for they frequently shifted their position by flying a few feet. The increased sociability was also apparent. Whenever an individual which was flying over the field alighted we always found that it had alighted near another, or near several. The butterflies could not, however, be decoyed by a dead individual, as is so easily done in the case of the pierids and the swallowtails.

In the later part of the afternoon individuals were seen flying toward one or another of the small trees scattered about the fields. Examination of the trees, however, disclosed only a single butterfly clinging to a leaf about four feet above the ground. But we left before the time these insects usually retire for the night.

On September 24, just a week after their first appearance in numbers in the fields, these butterflies were noticed at various places in the city of Washington, even in the business district. On the following day they were rather frequent about the city, always flying in a leisurely and aimless manner at a height of usually from eight to ten, but sometimes from fifty to a hundred feet or more above the ground. They remained frequent in the city until well into October.

On September 26 another visit was made to the Cabin John meadows. In the northern half of the main field there were a few scattered butterflies feeding on the goldenrod—perhaps a dozen were seen in all. This is but little, if any, in excess of what would be expected at this date in a normal season. Half a dozen of the butterflies were caught. One was freshly emerged, with the violet iridescence at the maximum brilliance, and the others were all fairly fresh—two or three, one possibly four, days old, judging from the condition of the iridescence on the fore wings. Certainly none of them had been on the wing for as much as a week.

It was rather late in the afternoon and the insects were getting ready to spend the night. Those in the northern half of the field simply hung from a goldenrod or aster or one of the upper shoots of some other herbaceous plant as they always do when engaged in intensive feeding.

There were none of these butterflies in the southern half of the field, but an examination of a grove of trees south of the field disclosed two which were flying about among the trees in a desultory sort of way and occasionally perching on the under side of small dead branches eight or ten feet above the ground.

It was apparent that all the butterflies which had emerged on September 17 and 18 had left the fields, with the possible exception of the two seen in the adjacent woods, though these were very likely younger. So far as these fields

were concerned the unusual abundance of this species was a thing of the past; conditions had returned to normal.

A peculiar fact in connection with the appearance of this butterfly in the meadows beyond Cabin John is that in these meadows its food plant is not to be found. The occurrence of this insect in great numbers in areas wholly devoid of the food plant has previously been noted. It would seem that immediately upon emergence the butterflies betake themselves to a locality abundantly supplied with suitable flowers, where they may gorge themselves with a minimum of effort.

There is nothing in these observations that shows any departure from the normal habits of this butterfly as it occurs throughout the season. The adult life is divided into two phases, a period of intensive feeding during which no sex instinct is manifested, and a longer period of extensive wandering apparently followed by reproduction, during which feeding is relatively infrequent.

The flight of this butterfly is always leisurely and more or less direct, contrasting strongly with the highly irregular and angular hurried flight of nearly all our other butterflies. The males display little or no interest in each other, and the individuals are always to some extent sociable. Males and females occur in equal numbers, and the habits and the flight of the two sexes are practically identical. This species is particularly fond of flying along the sea coast and along rivers at all times, and on any day throughout the summer wherever it is common individuals may be observed flying in a leisurely manner at a great height. Over water the flight is more rapid and direct than over the land, and the wings are moved continuously.

If the multitudes of these butterflies at Cabin John were developing just as the same number of individuals scattered throughout the summer would have developed, it becomes evident that the so-called migrations of this butterfly are really nothing more than the collective expression of the normal habits of each of the individuals taking part in the migration. A very large number emerging from the pupa at the same time naturally engorge themselves together and then reach the traveling phase of their adult life simultaneously. So we see in the air large numbers together instead of merely isolated individuals. The appearance of the milkweed butterflies in swarms means simply, I believe, that something has occurred which has caused large numbers to emerge at the same time.

The direction taken by these swarms in a migratory flight is usually more or less directly toward the south, and this is especially true in the central portion of the continent, where they are most conspicuous and most frequently observed. But they do not always go south. Two migrations have been reported from the vicinity of Washington. In one the butterflies were flying south across Chesapeake Bay in the face of a stiff breeze, and in the other they were flying north with the wind. Those that we saw were going west with the wind.

It is most unlikely that the southerly direction of most of the migrations of this insect which have been reported has more than a coincidental relation to geography. It is far more likely that it is merely a function of the prevailing wind plus the local geographical features, especially rivers and the sea coast. The migrations of this butterfiy are probably mere aimless wanderings having their origin in the natural wandering habits and the tendency to fly in a straight line inherent in each individual, and taking their direction from the prevailing late summer or autumnal meteorological conditions.

There is no real evidence of a north-

erly migration in the spring. In the early spring this butterfly is singularly inconspicuous. The worn and faded individuals fly very near the ground and are easily overlooked. They have been reported, however, from as far north as this insect is really common in New England. Furthermore the first brood appears in June at approximately the same time in New England and in the vicinity of Washington, which would scarcely be the case if they or their parents were immigrants into New England. The truth seems to be that, although most of them die during the winter, throughout the region where this butterfly is common a few survive and these survivors from the preceding year give rise to the next summer's population.

It is interesting to note that the abundance of the milkweed butterfly in eastern Massachusetts and southeastern New Hampshire in the autumn of 1888, just as the abundance in the vicinity of Washington in 1930, followed a summer in which the insect was unusually scarce.

Another type of butterfly migration seems to originate in the inability of the males of certain species to live together in a given area if their number exceeds a certain maximum.

Familiar to every one in late summer is the sight of a shrinking puddle surrounded by a muddy patch which is enlivened by a greater or lesser number of butterflies usually grouped in little companies, each company as a rule including butterflies of only a single kind, or at least of only a single color. The most conspicuous and most characteristic puddle butterflies in the more or less immediate vicinity of the District of Columbia are all pierids—*Colias philodice, Eurema lisa, Catopsilia eubule* and *Eurema nicippe.*

In connection with puddle butterflies it is noticeable in the first place that they are all males, and in the second place that they are all freshly emerged. It is frequently observed that on the appearance of a new brood the males are first seen in numbers about the puddles, later becoming common in the fields.

The occurrence of puddle butterflies seems to bear little relation to the amount of available water. In a normal year puddle butterflies will collect in numbers shortly after a rain when there can be no question of a sufficiency of water in the fields. On the other hand, in the exceptionally dry summer of 1930 when the numbers of all the butterflies were greatly reduced, the puddles and muddy patches in the vicinity of Washington were entirely deserted—not a single example of even the commonest of our puddle butterflies was to be found about them.

The true explanation of the puddle butterflies seems to be that they are young males from overpopulated areas in which they are incessantly tormented by other males and from which they escape to more peaceful surroundings. Requiring water, they naturally resort to the puddles, about which, in the absence of the rivalry excited by the presence of females, they fail to develop their usual pugnacity and instead become gregarious, flocking with others of their kind or with males of several kinds until they become fully mature, when they either return to the field from which they were originally driven or, remaining more or less gregarious, wander away.

The appearance of puddle butterflies—at least among the pierids—seems always to be evidence of an excess in the number of individuals of the species concerned in any given area. It is primarily evidence of a growing pressure of population—that is, of overcrowding.

Many, perhaps most, of the young males seen about puddles are only temporary exiles, returning to the fields when they have sufficiently matured and as the older males die off. But it is

quite probable that many of them would be unable to find a place for themselves in the fields and would therefore be permanently exiled. Such males would be very likely to wander—the males wander in any case—and in their wandering they would presumably fly in a more or less straight line against the wind, which is the usual habit of the individual males of our common species when simply traveling.

It is a reasonable assumption that surplus males of our two local pierids most given to migratory flights—*Catopsilia eubule* and *Eurema lisa*—would normally wander away, flying primarily against the wind. Being gregarious and very readily decoyed, even by crude paper imitations, other surplus males would tend to join them until finally a considerable number would be assembled in a loosely gregarious swarm. The nucleus of such a swarm might come from puddle butterflies, from exiled males in any area, from persecuted males still in the fields or from all three sources. Elimination of surplus males may take place when, so far as we can see, there is no actual evidence of overcrowding in the fields, especially in the case of such large, powerful and very active species as *Catopsilia eubule.*

The migrations of the pierids of the types corresponding to our *Catopsilia eubule* and *Eurema lisa* seem to be nothing more than the end-product of the natural process of the elimination of surplus males.

Much has been written regarding the southerly late summer and autumnal migrations of *Danais plexippus,* but little has been said of the northerly migrations of *Catopsilia eubule* which from time to time take place at the same season and in the same regions in the coastal area. As a concrete instance of migrations in opposite directions taking place simultaneously, I may say that in the very field where I observed *Danais plexippus* going west with the wind I have seen the males of *Catopsilia eubule* flying high and very fast eastward against the wind.

If the migrations of these butterflies were anything more than relatively simple responses to the meteorological and other physical conditions—that is, if they served any purpose beneficial to the individuals taking part in them—we should scarcely expect to find two primarily tropical butterflies migrating in opposite directions in the same place simultaneously, especially north and south.

The solution of the problems connected with the migrations of butterflies lies, I believe, in an accurate and detailed knowledge of the normal sequence of habits of both sexes of the species involved—in the case of dimorphic or polymorphic forms of both sexes of each of the forms—from the time of emergence from the pupa until death; of the real or apparent changes in the normal habits induced by overcrowding or by the destruction of the food plant; of the relations of the individuals of a species, particularly the males, to each other and to related species in the same region, and of the relations of the individuals of a species to the meteorological and geographical environment.

MENTAL DIFFERENCES AND FUTURE SOCIETY

By Dean ARLAND D. WEEKS

SCHOOL OF EDUCATION OF THE NORTH DAKOTA AGRICULTURAL COLLEGE

LIBERAL thinkers of the eighteenth century believed that with education free to all a great leveling of social inequalities would result. The cry of the times was for schools and popular education. Outraged by the evils of aristocracy and the abasement of the masses, the theorists of revolution in France, America and England advocated more and sometimes better education. From Rousseau to Noah Webster voices called for the diffusion of learning in the interests of greater social equality.

In their drive for popular education as a means of realizing political democracy, the eighteenth century liberals concerned themselves little with educational details and courses of study, striving first for the open door; and if the founding fathers knew how widely human ability to learn varies they said nothing about it. Common observation told them that there were men foolish and men of talents, but the shadow of the IQ had not fallen across the page in those days. Give society a popular educational system, thought they, and the hierarchy of privilege would crumble. Illiteracy marked a caste; the essentials of knowledge purveyed through the schools would give power to the masses.

To us it is interesting that differences in human ability entered so little into the discussion of the adequacy of the people to maintain democratic institutions. Without education the people were felt to be unfit for self-government; but that with education they might still be lacking seems not to have occurred to any one. It has remained for us to realize, in a time of the widest extension of educational opportunity, that there exists a range of mental ability that offers some very hard nuts to crack for exponents of democracy. The slump in democracy has coincided with the findings of intelligence tests.

With findings such that he who runs may read, there is not much doubt left about how we differ, from one end of the curve of intelligence distribution to the other, and we have discovered "that the number of people of relatively low intelligence is vastly greater than is generally appreciated."

Abundant and convincing is the literature of mental tests, and essential facts outside the pale of controversy give pause in social philosophy. Consider how widely we differ:

	100,000,000 PERSONS	IQ
250,000	"Near" genius or genius	140-up
6,750,000	Very superior	120–140
13,000,000	Superior	110–120
30,000,000	High average	100–110
30,000,000	Low average	90–100
13,000,000	Dull	80– 90
6,000,000	Borderline	70– 80
750,000	Moron	50– 70
250,000	Imbecile and idiot	50–down

(*Based on data from Sandiford*)

With so many persons in the lower groups it must be that we are surrounded by "a number of people of relatively low intelligence." Carlyle said that the population of England was thirty millions, "mostly fools." A lawyer who looked at the foregoing table said he had always supposed there were a great many more morons than there are. Yet most of us who face the table are probably brought to a realization that from our youth up we have tended to idealize society, and are compelled to readjust our appraisals downward. Even if we plead guilty to a tendency to designate as morons persons we dislike, or who differ from us, we are yet scarcely prepared for "this mass of low

level intelligence." The upshot is that probably most of us are depressed, not to say unsettled, by considering the evident distribution of native ability in mankind.

Knowledge of range of ability will of course have repercussions upon theory and practice in government, upon education, literature, journalism, the theater and propaganda and advertising. For good or ill, use will be made of the accepted facts of intelligence, and exploitation and philanthropy will not escape their influence. We shall simply not be able to think as we used to think, when once the fact of mental range is burned into consciousness as an ever-present datum. The revolution in our thinking will be like that following the doctrine of evolution or the Copernican theory. To-morrow will not be as yesterday; dreams of human perfectibility and equality go glimmering, when we fear that half of the people can be fooled all the time. How swift the reaction to the new knowledge, witness the uncanny appropriation of a new province of low level suggestibility by propaganda. Until the fuller resources of gullibility had been probed by daring pioneers of popular psychology, no one claimed that you could get away with murder. The mind of the multitude has become a more real bonanza than in the days of Phineas Taylor Barnum, whose horrid estimate that a "sucker" is born every minute appears somewhat too low, by a rough calculation employing terms as informed as possible with the spirit of the great showman.

Our attitude toward the foolish we shall change, even as we have changed our attitude toward the insane and the sociopath. We have somehow commonly felt righteous when denouncing "fools." The fools have had the awfullest time, and all without their fault; they have been fair game for ages. The psalmist and the proverb maker, the satirist and the pedagogue all took their flings at the mentally short or plied ferules and adjusted the dunce cap. This is not the place to go into the harrowing tale of the social cannibalism that claimed the person of low IQ throughout the centuries, but the thought is ventured that the popular attitude towards the lower brackets of mentality has been no more justifiable scientifically than would be imprisonment on a charge of red hair or capital punishment for inheriting a Roman nose as a structural feature of one's own countenance. For humility's sake, let us reflect that intelligence is relative; if we encountered a race who could master geometry in an evening we should all be morons. The fool has been in no position to defend himself, and as a result has of course been unjustly blamed. Though many old doctrines and practices, escape devices in the interests of our own comfort, have been given up, the fool-baiting complex dies hard. Great poets, like Milton and John Dryden, did not hesitate to lambaste other persons for lack of intelligence; even the pulpit echoes scorn for the mentally deficient, whose handicap is as biologically reputable, no matter how inconvenient, as, at least, is the vermiform appendix. Ultimately the fact of mental range will be accepted with emotional equanimity, no matter what else happens.

Much may happen. While theorists are reconstructing their views of man as made, the affairs of the day go forward in the general direction of lines of least resistance, and the findings of mental tests are scarcely a step ahead of the unfolding of a daily record rich with items of practical application. Rates are what the traffic will bear; various and sundry pressures are made nicely correspondent to levels of intelligence; institutions and business do in a way hold the mirror up to nature. While there is enough uncertainty about intelligence in individual cases to keep up

excitement, in a rough way what happens is a measure of what the audience is adapted for.

Now "the blunt person is characterized by huge tolerance of absurd contradictions." He sees no absurdity in a reference to a road to town that is all the way down hill there and back—and gives himself to the instalment plan. He reads believingly that western New York State apples supplied the table of Queen Elizabeth, and accepts his party platform, and votes as usual.

Failure to note significant omissions reveals the deficient mind. Show to a mentally deficient person the picture of a wheel with the hub missing and he will not be conscious of the omission; with him there is no adequate sense of the completeness of evidence, no critical faculty at watch for essential elements. The trait in question prevails among the lower levels, mentally, of the consuming public, a fact taken advantage of by the advertiser who profits by leaving things out of the copy, leaving, as it were, the hub out of the wheel and inducing the credulous to think they are getting a wheel entire. An advertisement which, no compliment to me, reached me through the mails offered colored reproductions of notable pictures at small cost, but failed to declare how many reproductions would be sent for my money and gave no information on their size. If the reproductions had been only the size of postage stamps the buyer would have had no case; he would have been "stung." A man told me this afternoon how he had bought stock in an oil well, to find out later that an oil well will run dry after about a year. When he bought the stock he failed to note the time factor in an oil well's production.

Repeating the thought of a passage is a test of intelligence; according to fulness and certainty of restatement is intelligence disclosed. How often are the very words from one's mouth garbled immediately within hearing. The fine art of accurate reporting does not flourish among the lower IQ's, a fact that accounts for the vast jungle of ill-founded rumor and sloppy newsiness in the daily run; conjecture is converted into positive assertion; speakers are misquoted, scandals invented.

In the defining of abstract words mental status is indicated, which terms are derivatives from experience and represent the essence of meanings. It is notorious how ill defined by masses of the public are such terms as religion, evolution, patriotism, democracy, temperance, socialist, anarchist, agnostic, Republican and Democrat. And "this mass of low level intelligence is an enormous menace to democracy unless it is recognized and properly treated."

The dissected sentence is a familiar device in the literature of mental tests. A bright child is capable of taking a look at the words, "A defends dog good his bravely master," and of straightening these out into a sentence; the bright child would, without waiting to be asked to organize the words, feel that something was wrong in their sequence. On the other hand, the very dull would be unable to get them right, or would possibly gloat over them with a sensation of recondite lore. It would be invidious to cite examples from books and publications, some of which achieve circulation, in which actual, definite, tangible and unequivocal meaning is about as much present as such as in the dissected sentence before its reformation.

The giving of differences and similarities is a touchstone of intelligence. Not much matters with those of low intelligence; they note differences slightly and have not the meticulous perceptions of quality of the mentally alert. The nice distinctions out of which spring literature and science are obtusely noted or wholly unperceived; thus, in society afflicted with extensive moronism, Christianity and church membership are synonymous; no distinction is made be-

tween real and nominal wages; education and schooling are the same thing; agrarian and industrial feudalism, chattel and wage slavery go unsuspected of identities, while exactions for private profit and taxation for social purchasing arouse reversely suitable sentiments. The debunking process which has attained magnificent proportions in our decade simply witnesses to the extravagant lengths to which such simplicities have run us.

Look where you will and consult any type of mental test, and the net result is an intensified conviction of the massive aggregate of mentality in the lower groups, correlated products of which are in daily evidence. Quack doctors and clerical pretenders ply their trades; sucker lists are compiled of interminable proportions; words rather than ideas count; political corruption and crime glorification obtain; silly notions win silly people in the rhythmic raids of fashion; there are: noise, jazz, speed, war and the man who would walk a mile for a brand. True, for every man, woman and child with IQ below 100 there are a man, woman and child with IQ above 100; but here consider those below the line, among whom is the "typical moron":

Graduate of a small but accredited high school. Spent five years to secure fifteen units. First year's work in university went poorly. Found to have mental age of about twelve and one half years. Good athlete. Good penman. Well dressed. Excellent manners. Entered a Greek letter fraternity. Father a banker. Mother apparently a superior woman. After K was dismissed from the university he was glad for "he could never learn books anyway." Good automobile driver. Memory span short. Unable to reproduce correctly simple geometrical designs. Could not imagine or think out new combinations of forms and of objects. Lacked resourcefulness and ingenuity. Unable to pick out or explain simplest kind of absurdities. Deficient associative bonds. Unable to find words of the same or analogous meaning, or to pick out essential likenesses and differences.—From "General Introduction to Psychology" by Griffith.

While such extremes and variety of intelligence have always been, outcomes under modern conditions must be awaited with interest. Knowledge increases the power of the dull, but multiplies disproportionately the resources of the superior; science means something directly to the lowly, but it gives unprecedented power to the gifted. As knowledge grows from more to more a wedge progressively separates the social fates of persons at different levels of native ability. Two illiterates of contrasting abilities would upon learning to read be still more different. Moreover, the remotenesses and complexities of modern commercial and industrial control baffle the lower orders of mentality, presenting nothing tangible as adversary. The manly art of economic self-defense through direct dealing passes when mergers and big business dominate. Economic manipulation governed by relatively high intelligence can be more persistently and hopelessly oppressive than face-to-face imposition. The bigness and inscrutability of manipulative processes leave the lower mentalities badly off for self-help. Advanced technical education means additional leverage against the mentally less endowed. A fact that our fathers did not see is that free schools do not remedy native differences of capacity. Says Pintner in "Educational Psychology," p. 144:

Thus a child with an IQ of 80 is unlikely to be able to complete the eighth grade successfully. Such a child ought to be given practical vocational training in the last few years of his school life so that at the age of fourteen he may be in some way prepared for his future work in the world. A child with an IQ below 90 will probably derive little profit from the ordinary high-school course. Children with IQ's between 90 and 100 will probably profit from some of the more abstract work. To grasp the symbolism, understand the proofs and make the generalizations required in algebra probably requires a minimum IQ of 110. It is doubtful whether children with IQ's below 110 should be advised to take the customary course at a liberal arts college.

Paternalistic changes in the school system looking toward special care are implied in the new knowledge of mental differences; from limitations of ability an accommodation of schools must follow. Indeed, the gearing of instruction to mental status is an ideal of teaching, and accordingly we should expect that junior colleges, vocational high schools, trade and continuation schools and special classes would reflect the discovery of the extent of mental differences.

In other fields than education, readjustments will occur in view of awareness of the persistent contrasts in human ability and the amount of low level mind. As suggestive of what may take place recall the accommodations of journalism to progressive ascertainments of the true character of mentality at the lower levels, ranging from the original yellow journalism to exhibits on the news-stands to-day. As to the "fool-proofing" of machinery, one might question whether it can proceed much farther, or whether assistance can go much beyond that rendered by telling one to "cut on this line," when facing the problem of opening a mere box of breakfast food. Our high-grade moron was an expert driver of the automobile, proof of the extent to which shortage of intelligence was provided against. Influenced by the findings of mental tests it seems probable that the operation of all sorts of machines of popular use, and participation in travel, commercial transactions, funerals and recreation will be made easier and less burdensome on attention and thought.

The climax of our interest lies, however, in the effects of the fact of mental range upon social and governmental policy. Will not accommodations necessarily be made there? Is not Mussolini perhaps a man who has peered into the sociological beyond, divining and capitalizing the truth of human differences? May not the great Russian experiment be soundly cognizant of the range of capacity? May not the political philosophy of the future be based squarely upon the recognition of the great mass of low level intelligence even as our early democracy was based upon the dogma of essential equality?

How, let me ask, can the 30,000,000 IQ's first below 100 compete successfully with the 30,000,000 IQ's first above 100? How will the 13,000,000 dull, dull as God made them, fare in a struggle against the 13,000,000 superior? Picture the scene with 6,750,000 borderline folk and their associated morons pitted against 6,750,000 of the very superior. Last scene of all, 250,000 imbeciles and idiots in every 100,000,000 of population as an antithesis to 250,000 of the brightest minds that ever flashed.

Will paternalism, as a reaction to exploitation under modern controls, to competition that can have but one outcome, be ushered in? It would mean oversight, maintenance, management and protection, and also imply a degree of disregard for what dependents think. Will not realization of the amount of moronic intelligence speed us on the way to paternalism?

The answer is indicated by various significant trends. The movement for old age pensions, the rise of the theory of high wages as a general economic benefit at a time of inefficient labor organization and of the "yellow dog labor contract," the assumption under President Hoover of superior-class responsibility for unemployment, the dole in England, the giganticism of life insurance, the plight of the farmers, who have failed to help themselves, the rise of large-scale philanthropy, the frequency of failures among small-business men, and the victorious chain store, do, taken together, attest to a tendency toward social reorganization on lines reflecting mental caste. With the ripening of institutions and the perfection of economic strategies, assuring steady increase of disproportionate benefits to the upper levels of intelligence, it can be only

through policies determined at the seats of power that, for example, in the United States, the farmer is not made a peasant or exhaustively exploited and put on a dole.

The potential subjugation of the lower groups is implicit in an economic absolutism of price. Beyond any political or social control is control by price. Millions with no voice in any price setting, with no part in contracts but acceptance of dictated terms, pay the price printed on the tag, knowing not the first thing about its fairness. The power exercised by the man who writes a nation's songs is as nothing compared to that of the combine that writes the price tag. In one of the romances of the future by H. G. Wells the lower social strata are represented as living underground, driven off the face of the earth. Such picturesque outcome is less likely to take place than that model tenements will be erected and that low IQ life will be regulated to a maximum of contribution to the upper strata. Cruel neglect and shortsighted indifference to the welfare of the lower levels are as unlikely as would be a recrudescence of dealing with the insane and the criminal after the manner of the Middle Ages. The poor, always to be with us if there is correlation between wallet and wisdom, will be less commonly regarded as blamable or responsible for their condition; and governmental paternalism, instead of being mentioned apologetically, will be regarded as the only logical policy of the state, while a commercial paternalism, of which the pension system of the Northern Pacific Railroad is only one example out of thousands, will round out a total effort grandly dramatizing the idea of a father caring for his children, not to say safeguarding the goose that lays the golden eggs. The lower IQ strata will probably be guaranteed against extinction or extreme degradation of standards of living by a diffused humanitarianism and an application of the principle of intelligent exploitation, tempered with fear of sabotage. It is, of course, quite possible that intellectual aristocracy of the Russian or the Italian type, while effectually disposing of the democratic tradition and striking down the idea of the wisdom of the common man, will nevertheless provide for him as he never has been taken care of before; the care he receives will be that of paternalism, vastly improved but logically heir to the feeding and housing of dusky plantation workers by their mental superiors in slavery days.

The rôle of the least capable citizens will be as heretofore that of assent, ratification, discontent, protestation, resolutions, mass meetings, jubilation, proud suffering and ostensible power, while less and less will actual self-government be realized. Technical management of the affairs of state must of course fall to those who are adept in law, engineering, administration and propaganda, whose work will be reacted to often with no greater aptness than that shown by the Romans who held emperors responsible for the weather. But a rough check on government action may be expected from the 50 per cent. who can scarcely qualify for balanced criticism or constructive suggestion. Through indirect suggestion and propaganda engineering the art of government will progress in the direction of allowing voters of lower mental qualification to believe their will is to be carried out. Nor can any one deny that it does not require the highest IQ to sense rottenness in the state of Denmark. Statesmen of paternalism and the administrators of commercial overlordship will have many a restless night—in fear of what the heathen in his blindness may do, mistakenly of course. The widened suffrage and the absence of educational and mental qualifications for voters give the state a fully representative character, but effectual participation in social con-

trol on the part of the least able must manifestly be slight.

What form the power to rule, derived from superior intelligence, will take, what scenes of paternalism will appear, remain to be seen. A modern version of noblesse oblige may allow a Ford to the IQ of 70, stiffen the blue sky laws against plunder and so carry on that nothing so obnoxious as throwing moronic instalment debtors into prison will occur. But the reflection of mental differences in the institutions of a high-powered age will surely be much unlike the picture of a pleasingly simple democracy. Even with the diffusion not only of knowledge but of knowledge of economics and the state, a sort of learning out of which the poor might build weapons and defenses, the disparity in shrewdness and reasoning leaves the field open to advantages to those who rank highest in native ability.

Paternalism? We can only hope that the lower millions may have great leaders and that the classes who have mental power by birth will conceive of the state in terms inclusive of the welfare of the mass, for the inequality of the brain cells is great.

THE DEVELOPMENT OF A MAGIC FORMULA

By EARL H. BELL

UNIVERSITY OF WISCONSIN

INTRODUCTION

IF we are to understand the development of such social phenomena as magic and totemism we must change our technique of approach.

For the most part, the method of anthropologists has been that of studying the phenomena as they exist and function in the so-called primitive societies. Using this material as a point of departure they have attempted to unravel the threads and thus learn how the complex developed. Thus far, except for establishing the elements or threads of the phenomena and their relations to each other, we have accomplished but little. As yet the processes of their combination remain obscure.

This is not at all surprising. Any one could take a piece of woven cloth, unravel it, study the materials used in it and tell the manner in which the threads were combined, but this would throw no light on the modern processes by which it was manufactured.

Our position in regard to magic is much the same. We have unraveled it, learned the materials of which it is made and know quite definitely how it goes together, but we do not know the processes by which it is put together.

The only technique by which we can study the processes of the development of magic is that of observing it grow up in contemporary society. We need not seek out primitive groups to find magic. It exists in modern society and, more significant still, is even now in the process of formation.

So far as I know, the only studies using this technique are those of Professor Ralph Linton, "Totemism in the A. E. F.," published in the *American Anthropologist* of June, 1924; and of Professor Kimball Young, "The Story of the Rise of a Social Taboo," published in the SCIENTIFIC MONTHLY of May, 1928.

The following account is a picture of the process of the development of a magic formula.

I

One of the perplexing problems which is constantly demanding more and more the attention of the Iowa farmer is the

increasing menace of the Canadian thistle (*Cirsium arvense*).

This weed, which is constantly moving southward and forcing itself upon the attention of the agriculturist as a major problem, is extremely difficult to eradicate, and in the face of the most persistent and resourceful efforts on the part of the farmers, directed by the various agricultural experiment stations, it has not only held the ground already invaded, but even continued its southward migration. An agricultural bulletin describes it thus:

> The jointed, horizontal root stocks are the most obnoxious part of the plant; round, slender, like tough white whip cords lying so deep in the ground as to be always sure of moisture, they creep in every direction for rods, even sending up new plants at intervals; if broken and dragged about by farm implements the pieces grow, so that ordinary cultivation but serves to spread the pest.

The extent to which the farmers recognize the necessity of eradicating it is shown by the methods of combat. It is a common sight to see a large patch of ground completely covered with tar paper in an attempt to destroy the weed by shutting it off from the sunlight. Another method used is to pour gasoline on the plant, saturate the ground around it and then set fire to it. Other farmers may cover the infested land with salt, which not only kills the thistle but sterilizes the ground for a period of years.

Such a problem, of course, occupies a prominent place in the minds and conversation of the farmers living in infested areas. At the noon hour during the threshing season the men often exchange information which they have about the pest, and tell of their friends' as well as their own experience with it. Often they will refuse to allow the machine to thresh for a farmer whose field is infested until all the other men in the "ring" have finished.

Out of this background has come a magical means of eradication, the development of which may be traced in the following narrative.

On or about August 25, 1925,[1] a hot, dry summer day, John M. and his son went out to their field in which was a small patch of ground infested with the Canadian thistle and cut the weeds off close to the ground with sharp hoes.

The next year they were much surprised to find that the thistles did not come up again. Mr. M. and his son talked it over between themselves and with their neighbors, one of whom contributed an old superstition that "everything has a certain day upon which it may be easily killed."[2] At this time it was decided that Mr. M. had discovered the Achilles' heel of the Canadian thistle. It could be simply and easily exterminated if it was cut down on August 25.

Such news was not long in spreading throughout the community and on the next August 25 many farmers went out armed with hoes in their war against the thistle. In some cases the battle was successful and in others it was not. Cases of failure, however, did not invalidate the discovery, but rather strengthened it, "For," contributed some of the old heads, "everything not only has its day but also its hour." They were on the right track and had only to perfect the formula.

By the summer of 1928 the idea had diffused throughout the county, and I have noticed it in the surrounding counties as well.

II

We may let the story rest at this point and analyze the conditions in the society underlying the development of the magic

[1] There seems to be considerable doubt as to the date, as Mr. M. did not realize the importance of the day until the following summer. One neighbor who saw him cutting the weeds claims the day to have been the twenty-seventh. This is a moot point in the community and both days have their followers.

[2] For the possible origin of this superstition in our culture see Eccl. 3: 4.

formula and the steps by which it developed.

1. We have a severe crisis which was felt by the group. The pest must be controlled for the welfare of the group which depended upon agriculture for a livelihood.

2. There is a great difficulty in coping with the situation which had never been defined, and all natural ways were extremely difficult, wasteful and unsuccessful.

3. Following the failure of the scientific methods disseminated through the channels of the agricultural experiment stations many individuals experimented with methods of their own.

4. The element of luck enters, in the form of the combination of several factors, such as temperature and lack of moisture extending over a considerable length of time which prevented the thistles from growing after they had been cut down.

5. The phenomenon is interpreted in the terms of an old and well-established superstition which builds up a false association between the time of an act and the result.[8]

[8] This type of association is common in magic.

6. The rapid diffusion of the trait is probably due to the fact that it was the corollary of a well-established superstition and seemed to meet the situation as well, considering its ease, as did the methods recommended by the experiment stations.

7. Cases of failure, which as with all magic are common, were met by the usual rationalization that the formula had not been followed exactly or that some item was still undiscovered.

III

In mentioning the wider aspects of this incident we should note the importance of the crisis or new undefined situation which is difficult to meet and in which scientific methods were extremely difficult and uncertain. In the second place there is the element of luck or chance which made this simple method appear successful, and in the third place a false association made in terms of an equally erroneous premise.

Were it not for the comparatively high development of a scientific culture it is not unlikely that such a phenomenon would persist and take on all the characteristics of a highly ritualistic magic formula.

SCIENCE SERVICE RADIO TALKS

PRESENTED OVER THE COLUMBIA BROADCASTING SYSTEM

PLUMBING THE DEPTHS OF THE EARTH

By Professor KIRTLEY F. MATHER

CHAIRMAN OF THE DEPARTMENT OF GEOLOGY AND GEOGRAPHY, HARVARD UNIVERSITY

To get to the bottom of things, to find out what makes the machine go, are ambitions worthy not only of the child but of the man. The real essence of the scientific spirit of research is the desire to see the unseen, to discover the secrets that are forever concealed from the casual observer but are frequently revealed to him who is sufficiently persistent in the quest for knowledge. This is just as true of the science of the earth as it is of the science of the stars. Until recently, knowledge of the earth has been largely confined to that which may be directly observed on land and sea. But in recent years it has become increasingly apparent that much which we ought to know is concealed beneath the surface on which we live and move. Some of the most fundamental questions, such as why there are continents and ocean basins, what makes the lofty mountain range stand above the lowly plain, can be answered only when we know the nature of the deeper interior of the earth. Many of our most valuable stores of petroleum and ore are so deep in the rocks of the earth's crust that their presence could never be inferred from what may be seen on the surface. Plumbing the depths of the earth is therefore a task of the greatest practical as well as scientific necessity.

The deepest mine which men have thus far dug is about 7,500 feet deep, only one three-thousandth part of the earth's radius. The deepest well which men have thus far drilled is about 9,000 feet, nearly one and three quarter miles, yet not much of a start on the long journey of four thousand miles from the surface to the center of the earth. As far down as man has gone he finds rocky material quite like that which he sees wherever the solid rocks of the earth's outer shell are exposed to view. The limits of deep drilling have not yet been reached, but at best this method of plumbing the depths of the earth can never do more than slightly scratch the earth's skin. Other methods must be used if we really want to know what is in the earth beneath us, and several are now at hand.

Earthquakes, for example, make their contribution to knowledge. Whenever one occurs, it starts a series of vibrations through the earth which spread in all directions like the ripples on the surface of a placid pool when a pebble is tossed into the water. These vibrations pass completely through as well as entirely around the earth and may be detected by sensitive instruments, called seismographs, designed for this purpose. At present there are nearly two hundred seismograph stations scattered over the surface of the earth at government observatories, universities and institutions for scientific research. Every violent earthquake is recorded on many of these instruments. Several times a year, old mother earth shrugs her shoulders with sufficient violence to shake the entire surface of the globe. Only close to the place at which the movement originates is it of sufficient intensity to cause any damage. At distances of only a few hundred miles it is usually quite imperceptible to human senses, but the vibrat-

ing waves are detected at distances of thousands of miles, in fact clear around the earth, by properly adjusted seismographs. Thus the progress of the waves as they advance through the solid rocks may be observed. Each wave is in fact a messenger which starts, let us say, in Japan and dives deep toward the center of the earth to emerge at St. Louis or Cambridge, Massachusetts, or London or Bombay with the news which it has picked up along the way. Its message is in hieroglyphics, the quivers of a jerky line traced by pen point or tiny beam of light upon the recording paper in the seismograph. Like a secret code, it must be translated before it can be understood.

The velocity at which the earthquake vibrations move through earth material is determined by the elasticity and density of the material encountered and by the nature of the vibration itself. In general, it takes about twenty-five minutes for the swiftest earthquake waves to travel by the most direct route from the point near the surface at which they originate to a point on the surface directly opposite on the other side of the globe. This route is of course through the center of the earth and is therefore about 8,000 miles long. This is about the rate at which such waves travel through glass or steel, and it indicates that the earth as a whole behaves as though it were composed of material as elastic and dense as would be a sphere of glass or highly tempered steel of its dimensions. No great ball of molten rock with a thin crust of frozen surface material could possibly behave as does the earth. The earthquake messages tell us unmistakably that the earth is much more solid than it used to be considered. Its interior may be very hot but it can not be essentially liquid.

But earthquake velocities vary from place to place within the earth. In general, the deeper the path the swifter the movement. This is largely due to the increase in density with depth. Each cubic mile of rock is under pressure equal to the weight of a column of rock one mile square and as high as the distance out to the surface. Such a column a thousand miles high puts tremendous pressure upon the rocks at a depth of a thousand miles. In consequence the rock at that point is compressed so that it transmits vibrations much more rapidly than it would do were it at the surface.

However, whereas pressure must increase rather regularly from surface to center, the travel rate of earthquake waves changes irregularly with depth. In fact, as these waves approach the center and pass through the material at great depths they are quite abruptly slowed down from velocities of eight or nine miles per second to velocities of only five or six miles per second. The only possible explanation of this fact is that the material there must be very different from that nearer the surface. In all probability, the central core of the earth is composed not of rock with high elasticity, but of a metal like iron which is far less elastic. Judging from the composition of meteorites, which presumably are samples of the stuff of which planets are composed, the earth's core is a mass of mixed iron and nickel.

This central core has a radius of about 2,500 miles and thus extends a little more than half way from the center toward the surface of the earth. It can not yet be told with certainty whether the metal of which it is composed is in a solid or a fluid state. Records of earthquake waves that have passed through it are exceedingly difficult to interpret, and much attention is at present being given to this problem.

Surrounding the central metallic core there are several successive shells of rock of somewhat varying composition as indicated by the various rates at

which the vibrations travel in them. These are all known to be quite solid although not necessarily crystalline. In fact it is quite likely that at a depth of only a few miles below the surface the rock is essentially a glass which can be deformed much more easily than such surface rocks as granite or sandstone. This presumably makes possible the movements of the outer crust which cause changes of level of the land along the seashore and give rise to mountains. Such movements are themselves the cause of earthquakes, which in turn provide us with important information concerning the nature of the earth's interior.

The rocks in the surface layer of the earth are notably different from place to place. In general those beneath the sea are heavier and more elastic than those beneath the land. In consequence the earthquake vibrations which travel around the earth through this outermost of its several concentric shells move at different rates. The vibrations of a California earthquake, for example, travel more rapidly toward the west through the floor of the Pacific Ocean than they do to the east through the continent of North America. Even within the continent there are important differences. Limestone generally transmits vibrations at much higher speed than does sandstone or shale.

This fact can be used to advantage in the attempt to discover the nature of rock formations a few hundred or a few thousand feet below the surface. There are many large areas of land throughout which the bed-rock formations are entirely concealed by soil, sand, clay or gravel. Some of these concealed rocks contain oil or other minerals of great value. For example, there is not the slightest suggestion at the surface of the presence of oil in the newly discovered oil field south of Oklahoma City. Yet the oil pool there is undoubtedly one of America's greatest reserves of petroleum. No geologist could have told from surface evidence that that locality was likely to produce oil, because the oil-bearing structure is not revealed in any way. The same is true of several of the important fields of the Texas coastal plain.

But in the last few years several methods of discovering valuable information about these concealed rocks have been perfected sufficiently to make them a great aid in the search for the raw materials upon which our modern industrial prosperity depends. Those methods of plumbing the depths of the earth are known as geophysical prospecting. They involve the determination of physical properties of rocks such as differences in elasticity, in specific gravity, in electrical conductivity and in magnetic attraction.

Take the first of these as an illustration. An explosion of dynamite causes a miniature earthquake. The vibrations from even a comparatively small explosion, say fifty pounds of dynamite, can be detected by properly designed seismographs at distances ranging up to five or ten miles. These vibrations travel at velocities which differ with the different rocks, and therefore the travel-time may be used as an indication of the nature of the rock traversed. If, for example, there is a great mass of rock salt, such as is found in each of the salt-dome oil fields of Texas and Louisiana, between the place at which the charge of dynamite is exploded and the recording seismograph, the vibration will come through in a much shorter time than usual.

Again, the rock salt is very much lighter than the ordinary rocks and so exerts less gravitative attraction. The differences are slight but they are sufficient to be detected by the torsion bal-

ance. This instrument is a very sensitive one, with delicate adjustments, which is designed to reveal slight differences in the force of gravity. Wherever there is a fairly large mass of either unusually light or unusually heavy rock material within a few thousand feet of the earth's surface, the gravitational field is distorted. The torsion balance indicates the amount and direction of this distortion and thus suggests to the observer the location of such rock masses. Salt plugs in the coastal plain of the United States are deficient in specific gravity, and therefore their presence may be revealed by the torsion balance.

Other geophysical instruments are now in use which indicate variations in magnetic attraction which may be due to differences in the amount of certain iron oxides commonly found in many of the sedimentary rocks as well as in some of the igneous and metamorphic rocks. The interpretation of the information gained from the use of the magnetometer, the torsion balance and the seismograph is extremely difficult. In many instances there are several equally rational interpretations which may be placed upon the same body of data. The use of such instruments in the search for oil or other valuable resources can not therefore be considered an exact science. The technique of operation requires great skill, but even greater ability is demanded in the art of interpreting the records obtained. Nevertheless these instruments have already justified the large expenditures of time and money that have been made with them. More than one hundred salt plugs, many of which are accompanied by valuable oil accumulations, have been discovered in Texas and Louisiana within the last five years by geophysical exploration.

To some, this method of plumbing the depths of the earth seems to hark back to the days of the charlatan with a divining rod or so-called "wigglestick." The new methods at first glance seem to be quite as mysterious as those of the water witch or oil diviner. As a matter of fact, there is absolutely no comparison to be made between the two. The geophysical instruments operate in precisely the same way regardless of the individual who observes them. They are in no sense dependent upon the psychology or other idiosyncrasies of the operator. Nor is there any representation that the physical apparatus indicates directly the presence or absence of petroleum. Geophysical explorations depend upon perfectly valid scientific principles and give definite information concerning certain characteristics of the rocks in the neighborhood of the stations at which the observations are made. These characteristics are of value as an aid in the interpretation of the underlying rock structure. Where the structure is favorable it is wise to continue the search for oil by means of the drill. Where the structure is unfavorable it is unwise to expend additional sums in drilling operations. In the last analysis, only the drill can reveal with certainty the presence and quantity of petroleum.

The entire science of geophysics, which has as its primary motive the discovery of facts concerning the interior of the earth, is still in merest infancy. A most attractive field for scientific research has at last been made accessible, but only a tiny fraction of the territory has thus far been explored. There is need for much more knowledge in all departments of this new science. In the light of the present situation it may be safely asserted that the next twenty or thirty years will reveal many times as much valuable information concerning the depths of the earth as is now available.

WHAT GERMS ARE MADE OF

By Dr. WM. CHARLES WHITE

U. S. PUBLIC HEALTH SERVICE AND CHAIRMAN OF THE COMMITTEE ON MEDICAL RESEARCH OF THE NATIONAL TUBERCULOSIS ASSOCIATION

WHAT is a germ? A germ or bacterium is the smallest living thing we know. But in spite of its exceedingly small size it is among the most important of all living things. Some germs are indispensable to us—we could not live without them—while others live at our expense, causing disease and death.

Germs are usually five hundred times too small to be seen by the naked eye. To understand what they are made of one must be familiar with the last few years of the journeys of man's mind into the unknown, and with the evolution of his special mechanical skill. Two great steps furnished our ability to separate individual germs and get them in pure strains. The first was made by Dr. Robert Koch, of Germany, who discovered the tubercle bacillus and founded modern bacteriology, and the second by M. A. Barbour in the United States about twenty-five years ago. Dr. Barbour is now in Lagos, Nigeria, studying yellow fever.

Koch found that germs placed in sterile water and shaken vigorously, when poured on a glass plate covered with sterile solid food stuff like coagulated egg, would start colonies from individual germs. By using a fine wire and touching one of these individual colonies he found that he could transplant one kind of germ on a new clean food supply and that this germ strain would multiply into other germs and that all the germs would be of one kind.

Barbour found that he could pick out from a suspension of germs one single germ. He did this by using fine flint glass tubing drawn out to a microscopic size in a gas flame. When one does this the tube always keeps its hole. Barbour found that this fine tube with its tiny little hole could be made to suck up only one of the germs when brought in contact with it under the microscope and that then this one germ could be planted on new food to grow a colony of its own kind.

As a result of the work of these two men we are able to grow enormous quantities of one kind of germ and chemists and biologists can study what they are made of. You may ask, "What is the use of studying such a thing?" Well, all the life of plants and animals and man is dependent on the work of germs in nature. Some germs are essential to life and others are very dangerous and cause most of the diseases of plants, animals and man.

Those plots of ground in which flowers, vegetables, trees and grass grow luxuriantly may contain one hundred and fifteen million busy germs in a half of a square inch. These germs are of many different strains, each strain doing its own work, such as taking nitrogen from the surrounding air and soil and forming first ammonia, then nitrites, then nitrates, which the plants can use and prepare again into organic nitrogen which can be used by animals and man. Germs set free carbon in the form of carbon dioxide into the air and the plants then take it up through their chlorophyl or green coloring matter which, combined with sunlight, builds up the carbon dioxide into sugars and starches and cellulose for the food of animals and man. Any one who makes home-made wine or beer to-day and watches the busy bubbling and fermenting that takes place can see the results

of germs at work setting free carbon dioxide which passes off into the air for the further use of plants and man.

All living things in their turn become sooner or later food for germs, to be broken up and turned over again into usable form in the grand cycle of carbon and nitrogen and oxygen in nature. All our breadmaking, our tanning, our curing of tobacco, the making of vinegar and sauerkraut, our cheeses, the food of our silos, our wines, are carried on or prepared for us by germ action.

But, as I have said above, germs are not always good to us for they also are the cause of nearly all the diseases of plants, animals, and man. Is it any wonder then that scientists are forever searching for what they are made of and how they work? By being able to understand them he may be able to develop ways of helping the useful germs do their work better and hindering the work of the harmful ones.

We now know many thousands of strains of germs more or less intimately. These are divided into classes, orders, families and species just as other living things are classified and every strain has its own peculiar work to do and its own peculiar way of doing it. You have heard how each species can be obtained in pure form and how each one of the germs in a pure colony is like every other germ. More than this, each germ is just one cell during both infant and adult life and because it is just one cell it offers to the chemist and biologist the simplest and purest form of studying the processes of living nature. It is not like man, made up of myriads of cells!

Until we understand the living chemistry of individual strains of germs and the contrasts between the strains of a family we will still be groping in the dark in our efforts to understand all living processes. It is probable by searching for the chemical differences in strains of one family of germs, the members of which look and act very much alike in the laboratory but which are known by other observations to act very differently in nature, that we may find the reasons for these differences. Already great progress has been made both in industry and in medicine. For example, by finding that different strains of a family of germs will grow on very simple food material, such as in water and a few salts, it is possible to subtract the sum of what was in the food from what is there after the germs grow on it and to find in what is left what the germs have made. It is possible further to take these products of the growth both from the food material and from the germs themselves and find both their chemical nature and what happens when we put them into animals that is their biological nature.

The studies that have been carried on by the National Tuberculosis Association with money raised by the sale of the Christmas Seal will serve as an illustration to show what the different strains of the tubercle bacillus, or the germ which causes tuberculosis, makes. In the acid-fast family of bacteria to which the tubercle bacillus belongs there are some fifty or more known strains. There are three well-known ones of the tubercle bacillus—the strain that causes tuberculosis in cattle, the strain that causes tuberculosis in man and the strain that causes tuberculosis in chickens. To this same family also belong the various strains of germs which cause leprosy. The object of the studies which the National Tuberculosis Association has been carrying on is to find what these germs are made of, how they do their damage and kill, and, if possible, how to interfere with their evil processes so that benefit may come to all those who are sick with tuberculosis.

You will want to ask, How can a germ made of one cell only contain enough power in its minute body to-

make a million like it in a day, each having the same quantity of all the substances that the first cell possesses? For like the widow's cruse of oil, it is a never-ending power, or the spark of life, always elusive. There are, however, some fractions of this life element that can be separated for further study. For example, each living germ has in it certain substances called ferments or enzymes. To most of you and in fact to everyone these names are only names, words used to tag a substance which we little understand. But we can make solutions of them. You are familiar with essence of pepsin, which is a ferment, and you see the work of an enzyme when yeast makes bread rise and when wines begin to boil. Likewise we can make solutions of the ferments of germ strains and compare their work. But we can do this only if we grow one strain of germ in sufficient quantity to provide us with enough material for study.

Each germ strain has its own peculiar enzymes and we know little enough about them, but when a single germ is put into a quantity of simple food solution it is its enzymes which start to work. These begin by creating currents similar to electric currents between the germ cell and its surrounding water and salts, back and forth, until inside the cell a change in internal chemical arrangement occurs and then suddenly two cells are made. Then from two cells come four, and eight, in regular progression until we have a vast number.

A second group of substances are the pigments. These also, like the ferments, are little understood but are peculiar to each germ cell. The pigments take their energy from the sun as electric currents just as the chlorophyl or green color of plants acts for the plants.

With these two tiny machineries operating all the while, the germs manufacture sugars of rare type, starches, albumins, fats, and a great variety of substances known as toxins and ptomaines. These complex substances of which the germ body is made and which are often peculiar also to the strain of germ cell can also be separated as solutions, purified and studied for their chemical structure and biological action. For instance, there are two very closely associated germ cousins that cause pneumonia in man, but although they both produce pneumonia they make entirely different sugars which can be separated in pure form. They are different both chemically and biologically and are very hard to break up except by boiling in acids. Recently however Dr. Oswald T. Avery, of the Rockefeller Institute, found a ferment enzyme in one of the germs of the soil of the blueberry bogs which will break up these sugars into glucose and carbon dioxide. The action of such a ferment is nature's way silently and efficiently of breaking up dangerous poisonous substances into simple useful parts which can be used by plants and animals to carry on their life processes. How different is the silent way of nature from the crude, often noisy way of man, in the laboratory. To do the same thing that the blueberry bog germ does man must boil with a strong acid. It is certain that we do not destroy poisons in our bodies by boiling with sulphuric acid.

Among the toxins and ptomaines that germs make, you know of the poisons of diphtheria, scarlet fever, smallpox, food poisoning. Each disease-producing germ manufactures its own toxin, some strains in a family more than others. These poisons cause fever, sickness and death even when they are separated in solutions from the dead or living germs.

Germs produce also fats and waxes. For instance, the tubercle bacillus

family produces a wax nearly like beeswax but in addition it produces several fats of very rare character.

When we consider all these substances that germs are made of, it would seem that the hope of the future lies in a study of the comparative chemistry of the different strains of each family in a systematic methodical way so that we will know in what chemical units are the causes for the differences between the germs of disease, and the germs that help us. When we understand where each family and each member of each family differs we can very probably strike at those differences in such a way as to make them either more active, if the germ is a useful and helpful germ, or make them harmless if the germ is dangerous.

SOME POPULAR MISCONCEPTIONS ABOUT THE AMERICAN INDIAN

By M. W. STIRLING

CHIEF, BUREAU OF AMERICAN ETHNOLOGY, SMITHSONIAN INSTITUTION

When I was a small boy, the Thanksgiving season always brought to mind rather confused pictures of the Pilgrim fathers alternately fighting off savage attacks of the Indians and receiving from them gifts of corn, pumpkins and turkeys. The general impression which I retained was that, while the Indians had occasional altruistic outbursts, on the whole they were savage and undesirable neighbors.

In the Peabody Museum at Harvard University is preserved what is probably the oldest relic in the United States procured by white men from a living Indian tribe. This is an Indian bow dating back to the early New England colonial period. An ancient label still adhering to the specimen reads as follows: "Indian bow, taken from an Indian at Sudbury by John Goodenough, who shot the Indian." A long and interesting tale of misunderstanding precedes the penning of this terse statement.

In the year 1608, Edward Harlow was sent in a ship by Captain John Smith of the new Jamestown colony to explore the Cape Cod region. When he landed there and the Indians came out to meet him, he seized five of them and carried them off, taking them with him to England. The next touch of hospitality encountered by the Indians of the Plymouth region was when Thomas Hunt was sent there from Jamestown in 1614 to determine the desirability of the site for colonization. When he landed the Indians came to meet him in a friendly manner. He invited them on his ship and as soon as they were aboard clapped them all, twenty-four in number, under hatches and carried them off to sell them as slaves to the Spaniards. One of the Indians who later escaped was brought back to Plymouth by Captain Dermer who attempted to regain the good will of the Indians of the region in 1619. However, the natives, in view of what had happened on the two previous visits, were not in a mood to parley.

The next year, 1620, was the year of the landing of the *Mayflower* and the Pilgrim fathers. It is not surprising that they had difficulty in making contact with the Indians. The first shore party that landed found several houses from which the Indians had fled. Near these were large pits filled with corn which the Indians had stored for their winter supply. The colonists promptly robbed the pits of all the corn which they contained and the houses of their

utensils, all of which they brought with them to the ship. Several days were spent by the colonists in cleaning out the corn caches of the neighborhood and in addition several graves were dug up and the articles accompanying the burials taken. Had it not been for Squanto, the English-speaking Indian who had been returned the previous year by Captain Dermer, the colonists would probably never have encountered the Indians on a friendly basis. Furthermore, without the instructions of the Indians in regard to planting, the colony would have failed from starvation the first year of its inception, and there would have been no Thanksgiving to celebrate.

The experience of the Massachusetts Indians was typical of the sort of greeting the Indians had received from the time of the first landing of Columbus. The fact that in many places they had the spirit to defend themselves against robbery and slavery gave rise to the first of our list of conceptions "that a good Indian is a dead Indian."

Despite his reputation to the contrary, the Indian was not by nature particularly warlike Tribes that in later days bitterly obstructed the invasion of the whites, were invariably, on first contact, friendly and hospitable.

Some of the tribes of the Great Plains practiced a peculiar sort of warfare as a manner of gaining individual prestige, and the Aztecs seemed to be on the verge of developing an idea unique among Indians: that of supporting themselves by conquest. Most Indians, however, avoided fighting whenever possible, but fought fanatically when driven to it.

Warfare among the Indians was not as a rule a tribal matter excepting in the case of defensive fighting for mutual protection. War parties were organized by individuals, usually adventurous young men. Any one might organize such a party and collect such volunteers as would accompany him. Frequently wiser old men would attempt to dissuade such an exploit but no one had authority to prohibit such a venture. Actual fighting was as a rule by ambuscade or surprise attack. Military tactics were never used until the benefits of organized fighting were learned from the whites.

The earliest of all the misconceptions about the Indians arose immediately upon the discovery of America, when Columbus thought he had reached the East Indies and therefore called the natives "Indians."

Early in the 16th century, when America became definitely recognized as a separate continent, Europe began to speculate upon the probable origin of the natives. By this date Christianity had become firmly entrenched as the religion of Europe. In keeping with the religious spirit of the age, a solution of the problem was first sought in Hebrew tradition. As a result there were soon circulated many publications purporting to demonstrate that the Indians were descendants of the "Lost Tribes of Israel." As there are certain basic similarities in the customs of primitive peoples throughout the world, it was an easy matter to demonstrate resemblances between the American Indians and the early Hebrews.

Speculation did not stop at this point, however. Energetic writers began to see resemblances between the pyramids and temples of Central America and Mexico and those of ancient Egypt or India. Others thought that they could see the hands of the Phoenicians or the Greeks in some of the customs of the Indians; in fact, most of the high civilizations of Europe, Asia and Africa were each supposed by some writer at some time to have been the point of origin of the Indian or of his civilization. Not content with having exhausted all of the known culture centers of antiquity, enterprising theorists had

drawn upon mythical or assumed civilizations in order to furnish parents for our orphan natives. The myth of Atlantis and the theory of a lost continent in the Pacific have furnished colorful material for fanciful accounts of forgotten migrations.

The story of tribes of "White Indians" is one of the most persistent of the legends connected with the alleged exotic origin of the Indians. As early as the seventeenth century Wefer noted the frequent existence of albinos among the natives of Panama, and there have been frequently occurring notices of these people since that time. The supposed ancestors of these groups have been variously attributed to the Norsemen, the Irish, and the Welsh.

In connection with popular ideas of this nature there might be mentioned the widespread belief in the past or present existence of such abnormalities as races of giants, pygmies or people with tails. The folk lore of the Indians contains many tales of giants and dwarfs to which credence has been given by white hearers in many instances. In old burials unskilled observers have frequently mistaken the skeletons of children for those of dwarfs. The fallacious idea of a race of dwarfs is probably most prevalent in the Pueblo region of the Southwest. This is due partially to the finding of the mummies of children, and partly to the frequent occurrence of miniature storage rooms with small doorways, these having been interpreted as the dwelling places of pygmies.

Never a year passes without at least one newspaper report of the finding of the bones of an alleged giant. These finds when investigated invariably turn out to be the bones of large mammals, fossil or otherwise, supposed by the discoverers to be human remains. In some instances actual human remains in a burial have become separated in such a manner as to give to the untrained observer the impression of abnormal stature.

It might be said at this point that the studies of anthropologists have demonstrated that the American Indians are essentially of one racial type, probably the basic type from which the Mongoloid peoples of Asia have also sprung.

There are a number of beliefs which have long held general credence concerning the existence of pre-Indian or non-Indian races in America. It was believed for a long time that the mound builders of the Ohio and Mississippi valleys and the cliff dwellers of the southwestern United States were not only racially distinct from the Indians, but possessed a civilization superior to them. These beliefs have persisted in spite of the fact that it is now well known that many of the mounds were erected during historic times, and their function described by early travelers. Many of the mounds when excavated contain numerous articles of European manufacture. The skeletons and artifacts found in the pre-Columbian mounds show that their builders were Indians with a culture differing in no material degree from their historic descendants.

The pueblo dwellings erected on the cliffs in the arid Southwest were in no way distinct from other pueblo dwellings either as to the nature and degree of civilization of their occupants or as to the period of occupancy. The cliff dwellings were inhabited simultaneously with the other southwestern villages throughout virtually the entire period of occupancy of this region, historic and prehistoric. We now know from the growth of tree rings in wooden beams found in the structures the exact years in which they were erected. Most of the principal cliff dwellings were edected in the years 1100 to 1300 A. D.

Probably no misunderstanding brought about as much ill feeling and

bloodshed between the Indians and whites as the difference in concept concerning the ownership of land. The land within the tribal boundaries belonged to the tribe as such. Neither the individual nor the family possessed vested rights in land although each family might appropriate for purposes of cultivation as much as they required of any unoccupied land within the tribal boundaries. It was therefore impossible for any chief, family, or any section of a tribe legally to sell or give away any part of the tribal holdings. Naturally any documents or purchases of this nature had no meaning to the Indians. The early settlers seemed never to have learned this fact. Regardless of any negotiations carried on by individuals, the Indians of course considered themselves ousted when the whites took possession of their lands.

The religious ideas of the Indian have been little understood by the layman. Such terms as the "Great Spirit" and the "Happy Hunting Ground" are inventions of the white man. The concept of a ruling, all-powerful deity is a political analogy applied to supernatural powers, which could be conceived only by a people aware of centralized power, such as existed only in the Old World. Far removed from this conception was the Indian belief in a multitude of spirits whose abode was to be found in both animate and inanimate objects. His rituals and sacrifices were conducted with the sole purpose of propitiating these spirits. The Indian in no way mixed his ethics with his religion. Moral principles of good or evil were not a characteristic of his deities, as his religion was purely practical. Consequently ideas of reward or punishment after death or any such spirit abodes as a happy hunting ground or an Indian hell were equally foreign to his conceptions.

The Indian was far behind his European successors in such matters as the control of natural forces and principles, although his observation and knowledge of the organic life of his environment was surprisingly full and accurate. Virtually every Indian was a born zoologist and botanist and a keen observer of nature. The depth and beauty of his philosophy and religion has been but little understood by the white man. As an artist, poet, orator and dramatist he has never been excelled.

It is unfortunate that a general knowledge of these facts comes at a time when in most regions of America the Indian himself has almost forgotten the old customs and the old beliefs. It is a curious fact that the generations to come will have a clearer perspective and understanding of the Indian than did most of his white contemporaries.

A DWELLER IN THE PINEY WOODS

By Dr. FRANCIS HARPER
SWARTHMORE, PENNSYLVANIA

For uncounted ages the piney woods on Billy's Island had stood in their matchless glory. Successive patriarchs of the forest had reared their topmost green sprays ninety or perhaps even a hundred feet toward the blue Okefinokee skies, while the seasonal breezes had played upon their needles, sending down soft Aeolian music to charm each passing generation of men, whether red or white. Here had roamed the Seminole bowmen, including Chief Billy Bowlegs himself, when deer had been as numerous as the cattle of later days. Here the Confederate deserter had made himself a snug retreat during troublous war-times. Here Maurice and Will Henry Thompson had come in 1866 on their earliest excursion to the region, finding a rich field for their literary gifts. At about the same period James Lee, great-grandfather of the present inhabitants, had settled here as a pioneer, winning a livelihood from the wilderness about him. Besides being historic ground, this had seemed, at my first rapturous sight of it in 1912, one of the loveliest of earthly spots.

Nine years later the great brown trunks of the pines, both longleaf and slash, bore the fresh scars of the turpentiners—those melancholy forerunners of the axmen and sawyers. Even so there were delights in store for one roaming through the gladelike woods on this morning of May 16, which had been cloudy and lowery since dawn. For a day and a night previously there had been rain in the great swamp. All the low undergrowth was still wet; saw-palmetto, huckleberry and gallberry spattered me with rain-drops as I brushed through their thick ranks. In almost any direction my view extended for a quarter of a mile through the level, open woods. The vegetation was at its fairest and greenest, and summer bird life was near its fullest tide, for in the Okefinokee mid-May is more summer than spring. The chant of the pine-woods sparrow was fitting music in this outdoor cathedral; the bob-white called its name; the brown-headed nuthatches chattered to each other in the tree-tops; the trill of the pine warbler sounded almost as soft and mellow as the murmuring of the trees in which it makes its home; and now and again other regular inhabitants of the piney woods, such as the joree, the yellow-throated warbler and the wood pewee, contributed their notes to the general chorus.

Presently I became aware of a distinct addition to these songs and calls among the pines—some shrill piping whistles sounding from here, there and yonder. Did this elfin sort of music originate from bird or amphibian? Where were the authors—on the ground, among the bushes or in the trees? How far away were they? For long I could make no headway in solving these questions. Whenever I endeavored to follow one of the sounds to its source, it would cease or retreat, only to be heard from other points. The thing was utterly baffling. I was becoming fairly desperate. But eventually I hit upon an expedient that often works in such contingencies. Carefully getting a bearing on one of the sounds from a certain direction, I moved off at an angle for some distance, then got a bearing from another direction. It now merely remained to proceed toward the point of intersection of these imaginary lines, which luckily fell

FIG 1 A HABITAT OF THE OAK TOAD AMONG SLASH PINES AND SAW-PALMETTOS ON BUGABOO ISLAND, OKEFINOKEE SWAMP, GEORGIA, JUNE 5, 1929

in a fairly open space At the last I got down on hands and knees, and cautiously advancing in this manner, had scarcely covered a yard when a little blackish toad, with a pale golden streak down its back, made a slight movement among the grass and saw-palmettos before me

Bufo quercicus, the oak toad! Here was a prize indeed No longer nor wider than the last joint of my fore finger, it is by all odds the smallest *Bufo* of North America, if not of the entire world It scarcely attains one tenth the bulk of its big cousins, the American toad and the Southern toad From the babies of these species it may be readily told by its vertebral streak, its relatively smaller head and the bright orange dots about its legs

While the little fellow before me remained placid and silent, others not far off continued at intervals their plaintive, high-pitched peepings. *pheep-pheep, pheep-pheep, pheep-pheep-pheep, pheep-pheep-pheep-pheep.* After several minutes of motionlessness on the part of both of us, my new acquaintance made a few leisurely forward movements, crawling with one leg at a time, lizardlike, with body off the ground. It was not until I poked a straw at it that it made hops of a couple of inches or so. Eventually it made a few such hops of its own volition, though still crawling for the most part It was interested in ants running about near it, turning its body to watch them and presently thrusting out its tongue to lick one up. For half an hour I watched it moving freely about within a few feet, but it did not venture to perform vocally, though the heavy showers that fell upon us should have stimulated it To witness that performance was a treat reserved for later occasions

The oak toad was originally described in 1840, from Carolina specimens, by the learned Dr Holbrook in his classical work on "North American Herpetology" It ranges from North Carolina to Florida, Alabama and Louisiana, and seems to be restricted to the Coastal Plain A lover of dry places, it is found within the Okefinokee only on the islands, such as Billy's, Honey, Jones, Chesser's and Bugaboo In the sur-

FIG 2 THE OAK TOAD IS CONSPICUOUS WHEN PLACED ON A PALMETTO LEAF CAMP CORNELIA, CHARLTON COUNTY, GEORGIA, MAY 24, 1929

FIG. 3. THE OAK TOAD'S PROTECTIVE COLORATION

MATCHES THE GROUND LITTER IN THE PINEY WOODS. CAMP CORNELIA, CHARLTON COUNTY, GEORGIA, MAY 24, 1929.

rounding region it ranges widely, being particularly abundant on Trail Ridge, between the swamp and the St. Mary's River. Since the driest areas are generally covered with pine barrens (including the so-called "oak ridges"), the toad is a very characteristic species of this habitat, living among the saw-palmettos, gallberries, huckleberries, oak runners, wire-grass and other vegetation making up the undergrowth.

The oak toad gives an impression of being particularly numerous at no great distance from the habitations of man. Is this perhaps correlated with the fact that man tends to exterminate snakes, which must be among the principal enemies of the species? Or is it a simple expression of the desire of both men and toads to occupy the driest available areas in this low country? In this connection I recall several days of heavy rainfall on uninhabited Black Jack Island in July, and several days of variable June weather on Bugaboo Island, where the only habitation was a small turpentine camp, just established. I recorded no oak toads on Black Jack and only a few solitary calls on Bugaboo, though June and July are in the midst of the vocal season. Snakes of various kinds appeared unusually common on the latter island, perhaps because of infrequency of both fires and men. On the other hand, it may be noted that both these islands appear somewhat lower and damper than other islands of the swamp where the toads are more numerous. So the absence or comparative scarcity of oak toads in wet and intermediate pine barrens very likely indicates a strong preference for the driest parts of the piney woods.

Although the larger toads of the East (American, Southern and Fowler's) are mostly crepuscular or nocturnal in habits, the oak toad is frequently found abroad and heard calling during the brightest hours of the day. Probably its tiny size enables it to escape many hazards that might befall the larger toads if they braved the daylight to as great an extent as it does. Furthermore, its variegated color pattern is highly protective in its normal surroundings (Fig. 3). When alarmed, it is apt to cower down, with head held close to the ground, so as to render itself still more inconspicuous than usual.

Rarely have I been able to note in what sort of a retreat it elects to spend its inactive hours. Once, on lifting a slab of wood lying on the ground in dry pine barrens, I found an oak toad occupying a little hole beneath it, about an inch and a quarter in depth and five eighths of an inch in diameter. At another time, while I was trying to maneuver one into position for a photograph, it suddenly backed down into a three-quarter-inch hole in the ground, where it remained peering out of the entrance. Probably the use of such holes for hiding-places is a general habit with the oak toad, as it is with its congener, the Southern toad.

As a vocalist, this is one of the most remarkable of the twenty species of tail-

less amphibians known in the Okefinokee region. Few can rival it in relative expansion of the vocal sac, and none can compare with it in oddity of shape of this apparatus. In spite of the toad's pygmy size, its shrill notes carry to a distance of probably a quarter of a mile.

Its vocal season extends at least from early May to the latter part of August. Heavy rainfall, combined with a temperature above 70° F., produces the right conditions for a tremendous outburst of peepings, either by day or by night. The toads then resort in great numbers to the cypress ponds, or to such temporary waters as roadside pools, puddles in cornfields or flooded grassland. The eager males take up their positions close to the water's edge, in grass, on sticks, pine-cones or clods of earth lying in the water or on floating chips. In moving to some new position, they may take bodily to the water, swimming actively along beneath the surface and pausing now and then to sprawl out with part of the head above the surface. While swimming, they hold the arms curved forward along the sides of the head, the fingers about reaching the snout. Meanwhile the hind legs furnish the motive power. The position of calling is generally out of the water, though at its very edge.

FIG. 4. OAK TOAD CALLING, WITH INFLATED VOCAL SAC.

IN A ROADSIDE DITCH NEAR SPANISH CREEK, CHARLTON COUNTY, GEORGIA. FLASHLIGHT PHOTOGRAPHS ABOUT 1 A. M. AND 1:20 A. M., JUNE 22, 1929.

The vocal sac, when fully expanded at the moment of peeping, takes on the approximate shape of an inverted sausage balloon, almost half the size of the toad's whole body (Fig. 4). It is somewhat compressed, with a greater vertical than lateral diameter. The part of the sac nearest the body has a milky white appearance, but the outer half is translucent and water-colored. In the slight pauses between some of the peeps the sac is deflated to about one half or one third the full size, but sometimes two peeps are given in such rapid succession that no time is allowed for the sac to become deflated to that extent. In the intervals between the series of peepings it collapses almost entirely. The sac is filled with air forced from the lungs, and apparently some of the same air is reinhaled into the lungs. Meanwhile the toad doubtless makes use of a valve, as the frogs do, for preventing the escape of air through the nostrils. The sides of the body are seen to be compressed as the sac swells out to its full size, and they expand again rhythmically as the sac is partly deflated between peeps. The distention of the body during the calling periods is so great that sometimes the toad seems able to touch the ground with only the tips of its fingers; or it

may have to leave one arm entirely suspended in the air (Fig. 4). The comical inflation of the tiny toad, combined with its earnest demeanor, makes a spectacle to be long remembered.

In 34 calling periods of several different individuals in June, the number of peeps ranged from 8 to 37, with an average of about 23. When the toad is in lusty voice, the intervals between calling periods last for only two or three seconds. The rate of calling varies from about 1⅓ to 2 peeps per second. The slower rate has been noted after the toads had been calling for hours and were perhaps becoming exhausted. The individual peeps are not given at uniform intervals. There is usually an appreciable pause between every few peeps, but marked variation renders it impossible to record a typical series of notes. The following will serve as random examples: *pheep-pheep, pheep-pheep, pheep-pheep, pheep-pheep, pheep;* and *pheep-pheep, pheep-pheep-pheep, pheep-pheep-pheep, pheep-pheep-pheep, pheep-pheep-pheep, pheep-pheep-pheep, pheep-pheep-pheep, pheep-pheep-pheep.*[1] These calls of the males serve a biological function in attracting the females to the bodies of water where mating is to take place.

Fair-weather calls, whether diurnal or nocturnal, are generally rather desultory. But when multitudes of the oak toads forgather during or after especially copious summer showers, the din produced by the elfin bagpipers is simply ear-splitting. Several such gatherings stand out in my memory. Two occurred in the late afternoon in rain-filled depressions in pine lands—one on Honey Island on July 3 and one near Hilliard, Florida, on August 16. Others were at night—at a cypress pond on Chesser's Island, July 16, and in a flooded field near Trader's Hill, July 3. On this last occasion, particularly, our eardrums were in a fair way to cave in; we had to shout to each other to make ourselves understood, and some of us felt the effects in our ears for several hours afterwards. In such a species, size is certainly no safe index of vocal power. During these extraordinary outbursts of vocal activity, when the mating madness is upon them, the oak toads are quite indifferent, even by day, to a person standing within a yard.

During the mating season, which apparently extends from May to August, each female probably deposits eggs at several different periods. A little past midnight on June 22, after a hard storm of the previous afternoon, I observed the act of oviposition in a roadside ditch near Spanish Creek west of Folkston. The male maintained an axillary hold with its right hand, and a supra-axillary hold with the left. The pair paddled along a few inches at a time with the use of their six free limbs. As they came to a definite pause every minute or so, some eggs were expelled and fertilized. While they proceeded toward the next stop, a curious little straight string or two of five or six eggs each could be seen dangling from the female, soon to become detached on a grass blade or other object in the water. In several observed instances, the string of eggs did not fall to the bottom of the shallow pool. Within another day or so this pool had more or less completely dried up, and so the laying had gone for naught. Since many of the waters in which the oak toad breeds are of a very temporary nature, the mortality among the eggs and larvae must be very high.

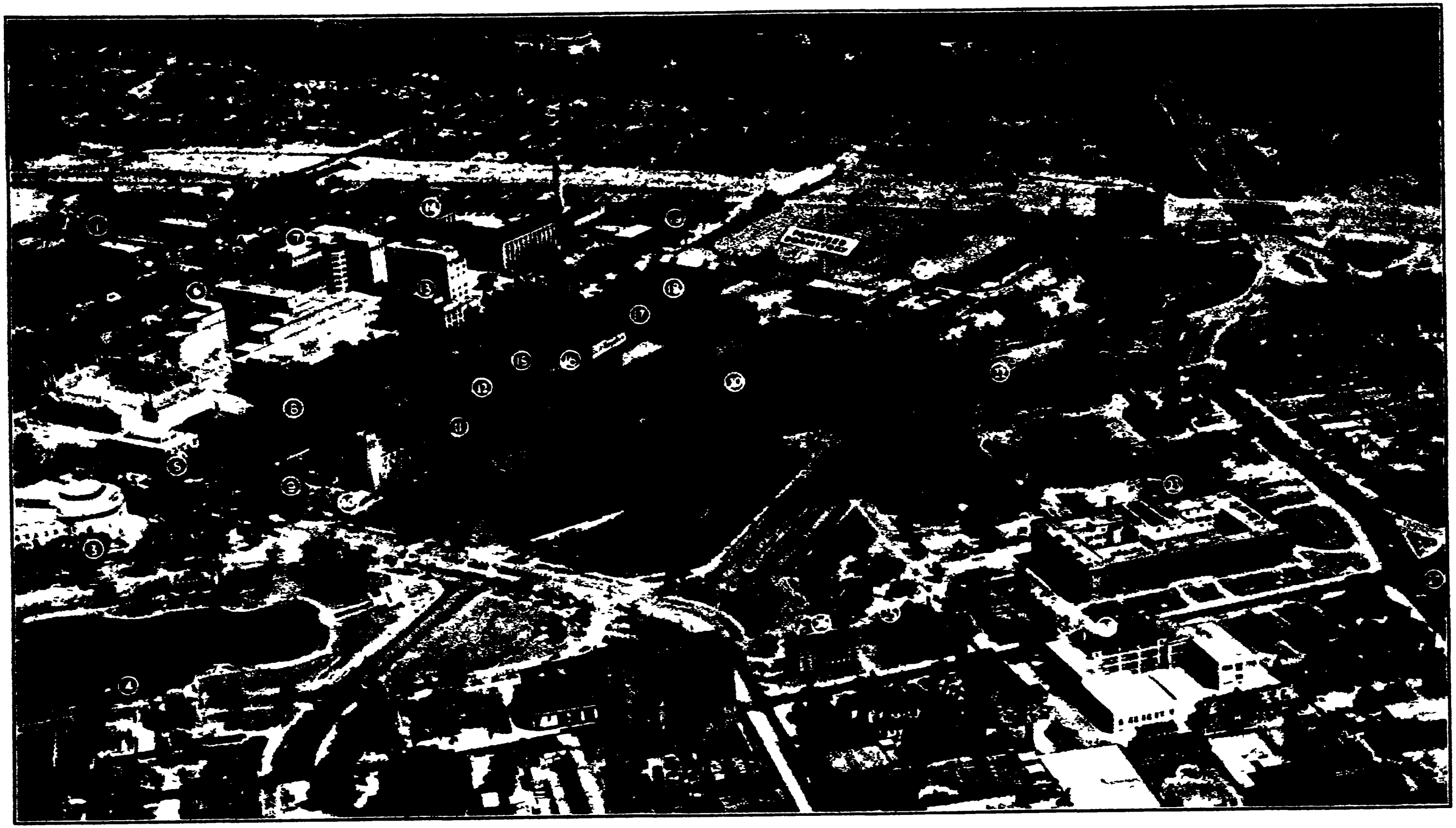
In common with some of the tree-frogs, the oak toad seems to pale out somewhat at night, its color pattern becoming lighter and more distinctly variegated. Its somber diurnal appearance in Figs.

[1] The notes joined by hyphens are given in rapid succession, while the commas indicate pauses.

2 and 3 may be contrasted with its bright nocturnal pattern in Fig. 4. Or is the latter possibly a nuptial rather than a nocturnal coloration?

In various respects—such as the sound of its notes, the shape of its vocal sac and the pulsating manner of inflating it, its diurnal activity, the nature of its eggs and its dwarf size—*Bufo quercicus* seems to be a rather aberrant member of its genus. All the other species of the eastern United States (and some of other regions as well) have a rounded vocal sac and keep it fully inflated during the single comparatively lengthy call, which consists of a generally steady trill, squawk or roar, as the case may be. Two Western species, *Bufo cognatus* and *Bufo compactilis*, by the possession of a vocal sac shaped much like that of *Bufo quercicus*, may show closer relationships with it, but comparatively little is on record as yet in regard to their habits and life histories.

I have had abundant occasion to esteem the remarkably keen knowledge that the Okefinokee residents possess of their wild animal neighbors. It is of particular interest, therefore, to realize how generally they have gone astray in the exceptional case of this tiny amphibian. While its shrill piping sounds through the piney woods, ask any inhabitant of the swamp or its environs to give heed to the notes and tell you what they are. Is it an Okefinokee penchant for accuracy in distinguishing between first-hand and second-hand information that leads him to respond in a manner less direct than usual, "Well, sir, folks *say* that's a black snake hollerin'"? Ten years ago practically every answer, if informative at all, would have been of this sort. Nowadays some will respond at once, with perhaps a not wholly concealed air of satisfaction over recently acquired knowledge, "That's a oak toad." I have become so used to the first type of answer that I confess I am sometimes rather startled by the second.



VIEW FROM THE AIR OF WESTERN RESERVE UNIVERSITY, THE CASE SCHOOL OF APPLIED SCIENCE AND SURROUNDINGS

(18) MARKS THE REGISTRATION HEADQUARTERS AND THE SCIENCE EXHIBIT. (11), (12), (15), (16) AND (17) MARK THE BUILDINGS OF WESTERN RESERVE UNIVERSITY IN WHICH MANY OF THE SESSIONS WERE HELD, OTHERS HAVING BEEN HELD IN THE MEDICAL SCHOOL (14). THE ADJACENT BUILDINGS ARE HOSPITALS. (30) MARKS THE GROUNDS OF THE CASE SCHOOL OF APPLIED SCIENCE. (23) IS THE JOHN HAY HIGH SCHOOL IN WHICH PUBLIC LECTURES WERE GIVEN.

THE PROGRESS OF SCIENCE

THE CLEVELAND MEETING OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE AND ASSOCIATED SOCIETIES

The Cleveland meeting was noteworthy in showing very clearly an awakening sense of broad social responsibility on the part of the association's membership. During the past few years there has been evident among those contributing to the programs an increasing tendency to broaden the approach to their subjects in such a way as to make their contributions of interest to a much larger circle. This change of attitude is evidence of the increasing self-confidence of American science, for it is always the timid worker who expounds his subject in such a highly refined and technical terminology that none but specialists in his own line are able to understand what he is talking about.

Of course a highly technical phraseology is and always will be necessary in discussing topics in all the more specialized subdivisions in all branches of science. Yet it is at the same time true that the deeper one goes into any subject, no matter how restricted the subject may be, the easier it becomes to express one's ideas in more or less simple language.

As a result of the increasing proportion of papers which, though incorporated in the technical program, are quite intelligible to any one with a good education, the gap between the so-called popular lectures and the more general papers on the section and society programs is rapidly being bridged. Indeed, at the Cleveland meeting a wholly satisfactory series of popular lectures could have been arranged by simply choosing contributions here and there from the section programs.

An unusual number of papers of outstanding importance were presented at this meeting. These papers included the first public mention of new developments or discoveries of great interest in several different lines. In other papers there was given further information on discoveries which had first been announced within the past twelve months

There were about four hundred and fifty more papers and addresses presented at the Cleveland meeting than were presented at Des Moines a year ago. Considerably more than half of this increase was in the field of biology and agriculture, together with anthropology.

This increase in the relative importance of the biological and allied sciences at the Cleveland meeting is partly to be explained by the fact that, in contrast to those lines of science more closely related to what is commonly termed industry, the twenty-two societies among which at the association meetings the biological and allied sciences were distributed still find in these meetings the best opportunity for their annual assemblies.

The economic as well as the other aspects of biology is still largely centered in our universities, colleges and allied and similar institutions, so that in biology there is not the dual allegiance —to academic activities on the one hand and to industrial life on the other—that has in recent years become so marked in other lines of science.

But the relative increase in the importance of the biological contributions can not be wholly attributed to its largely academic aspect. It is at least partly due to a relative increase in the general interest in biology itself.

A striking feature of the meeting was the large number of young men and women who attended the sessions and presented papers. This was of course partly due to the accessibility of Cleveland in reference to the scientific centers

MEMBERS OF THE EXECUTIVE COMMITTEE OF THE AMERICAN ASSOCIATION

SITTING FROM LEFT TO RIGHT: DR ROBERT A. MILLIKAN, RETIRING PRESIDENT OF THE ASSOCIATION; DR. THOMAS HUNT MORGAN, PRESIDENT; DR. J. MCKEEN CATTELL, CHAIRMAN OF THE EXECUTIVE COMMITTEE. STANDING: DR. BURTON E. LIVINGSTON, DIRECTOR OF THE LABORATORY OF PLANT PHYSIOLOGY AT THE JOHNS HOPKINS UNIVERSITY, PERMANENT SECRETARY, NOW ELECTED GENERAL SECRETARY; DR. HENRY B. WARD, HEAD OF THE DEPARTMENT OF ZOOLOGY AT THE UNIVERSITY OF ILLINOIS; DR. DAVID R. CURTISS, PROFESSOR OF MATHEMATICS AT NORTHWESTERN UNIVERSITY. MEMBERS OF THE EXECUTIVE COMMITTEE NOT SHOWN ON THE PHOTOGRAPH ARE: DR. FRANK R. LILLIE, CHAIRMAN OF THE DEPARTMENT OF ZOOLOGY AND EMBRYOLOGY AT THE UNIVERSITY OF CHICAGO, GENERAL SECRETARY; DR. KARL T. COMPTON, PRESIDENT OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY; DR. JOEL H. HILDEBRAND, PROFESSOR OF CHEMISTRY AT THE UNIVERSITY OF CALIFORNIA, AND DR. VERNON KELLOGG, PERMANENT SECRETARY OF THE NATIONAL RESEARCH COUNCIL.

in the northeastern section of the United States and southern Canada.

For its healthy development science depends on young people with ideas and with courage to expound them. It is gratifying, therefore, to find that a large proportion of the papers on the program were given by contributors whose names are not as yet to be found in the pages of "American Men of Science."

The annual meetings of the association serve three purposes: They provide an opportunity for the exchange of ideas among research workers in the same or similar lines of science; they afford an opportunity for bringing science to the general mass of the population upon whose appreciative support scientific advance is ultimately dependent through the medium of a sympathetic press; and they serve as a forum for those just embarking upon a scientific career.

It may be truthfully said that at the Cleveland meeting the last two aims were more successfully served than has ever been the case before, while the first in no way suffered by the emphasis on the other two

Besides the interchange and diffusion of scientific thought and of the scientific spirit through the presentation of technical papers and of addresses, and also through social assemblies, the association's meetings are now featured by exhibits of various kinds, both commercial and non-commercial. At Cleveland there was noticeable a marked interest in these exhibits over and above the more or less casual notice which they have attracted at previous meetings.

It is not possible to say for certain whether the increase in the number of people constantly in the exhibit hall was due to the attraction of the exhibits themselves, or whether it was due merely to the fact that the exhibits were more centrally located in regard to the meeting places than has heretofore been the case.

The success of a meeting is by no means a matter concerning the membership of the association alone. It depends very largely upon the spirit in which the association is received by the population of the city wherein the meeting is held.

The association owes the City of Cleveland, the Western Reserve University and the Case School of Applied Science a lasting debt of gratitude not only for the cordial reception of its members during the meeting, but also for the most excellent, thorough and comprehensive manner in which the laborious and intricate work of preparing for the meeting was handled.

AUSTIN H. CLARK

THE SCIENCE EXHIBITION

THE American Association for the Advancement of Science, at the recent meeting in Cleveland, made a new gesture in keeping with its underlying policy of making the advancement in science intriguing and understandable to the general public. This new move was the installation of enticing exhibits illustrative in one way or another of the advances of science through research. It is not feasible nor even desirable to recreate the research worker's laboratory, but rather to set out one or more illustrations from the laboratory which would have meaning and interest to the lay public, as well as to the scientist not versed in that particular field of endeavor.

It is assumed that the botanist stands on about the same footing as the high-school student when evaluating an exhibit in the physical sciences. Moreover, the physicist is generally fascinated by a clever, objective presentation

THE EXHIBIT OF THE AMERICAN MUSEUM OF NATURAL HISTORY

A PHOTOGRAPH OF THE EXHIBIT SHOWING THE WORK OF PROFESSOR HENRY FAIRFIELD OSBORN ON THE TITANOTHERES.

in physics when it is in a field in which he has only a vague understanding. Therefore the preferred exhibit is directed to an intellectual age of about fourteen

There are many elements entering into a general evaluation of an exhibit. The most important is visitor participation If the set-up is so designed that the visitor can push a button, turn a crank or otherwise make a demonstration for himself, the maximum interest is most certain. Next in interest are those exhibits in which a demonstrator causes a sequence of performance. But the cleverness of the demonstrator in correlating his speech and action is quite as much a factor as it is in any stage performance. Third in order of merit are those exhibits automatically in motion and showing some progression in illustrating a fact or a theory. Live mice being chased around a small stage by a disagreeable light or by electrical shocking devices of different frequencies from different parts of the cage would come in this same category. Static exhibits in glass cases are at about the worst disadvantage and only one degree better than wall posters, charts and tabular material.

However, it must be admitted that in a collection of exhibits there is an indefinable value in the correlation of the exhibits, and the composite eye impression has a value which is just as im-

portant, even if indefinable, as the eye impression that one gets upon entering a home, a department store or a railway station.

At the Cleveland meeting there were, besides the commercial exhibits, presentations in the diverse fields of science from the American Museum of Natural History, the Carnegie Institution of Washington, the U. S. Bureau of Standards, the Crile Laboratories, University of Chicago, the Bell Telephone Laboratories, Electrical Research Products Company, the Boyce-Thompson Institute, Leeds and Northrup Company in cooperation with the Museum of Science and Industry of New York, the Acoustics Research Laboratory of the American Steel and Wire Company, Blodgett Memorial Hospital, the Cleveland Clinic, Westinghouse Electric and Manufacturing Company, Dr. C. W. Kanolt.

These were all good when judged by the sustained interest of the crowds and by the interest of the news services. I am informed that the newspapers gave almost as much space to the exhibits as they did to the remarkable new achievements presented to the world for the first time in the form of papers.

It should be added that commercial scientific establishments are of the utmost importance to scientific advance. Schuster, in one of his books, has said that the advance in science seems to have followed the advance in the instruments of precision that are made for the use of the scientists. The public does not know the whole story of merit in the advance of science unless it also knows of the work that is being done by these commercial scientific establishments. It was observed at Cleveland that there was very great interest on the part of the general public, as well as by the visiting scientists, in the commercial exhibits. In fact, this intellectual curiosity on the part of the public seemed at times to be embarrassing to the men with this type of exhibits.

At future meetings a special effort should be made to enhance further the mutual profit to the commercial exhibits, as well as to the general public. Moreover, the commercial establishments will find in each large city a great many potential amateurs among the public who may develop into at least quasi-scientists and users of scientific equipment.

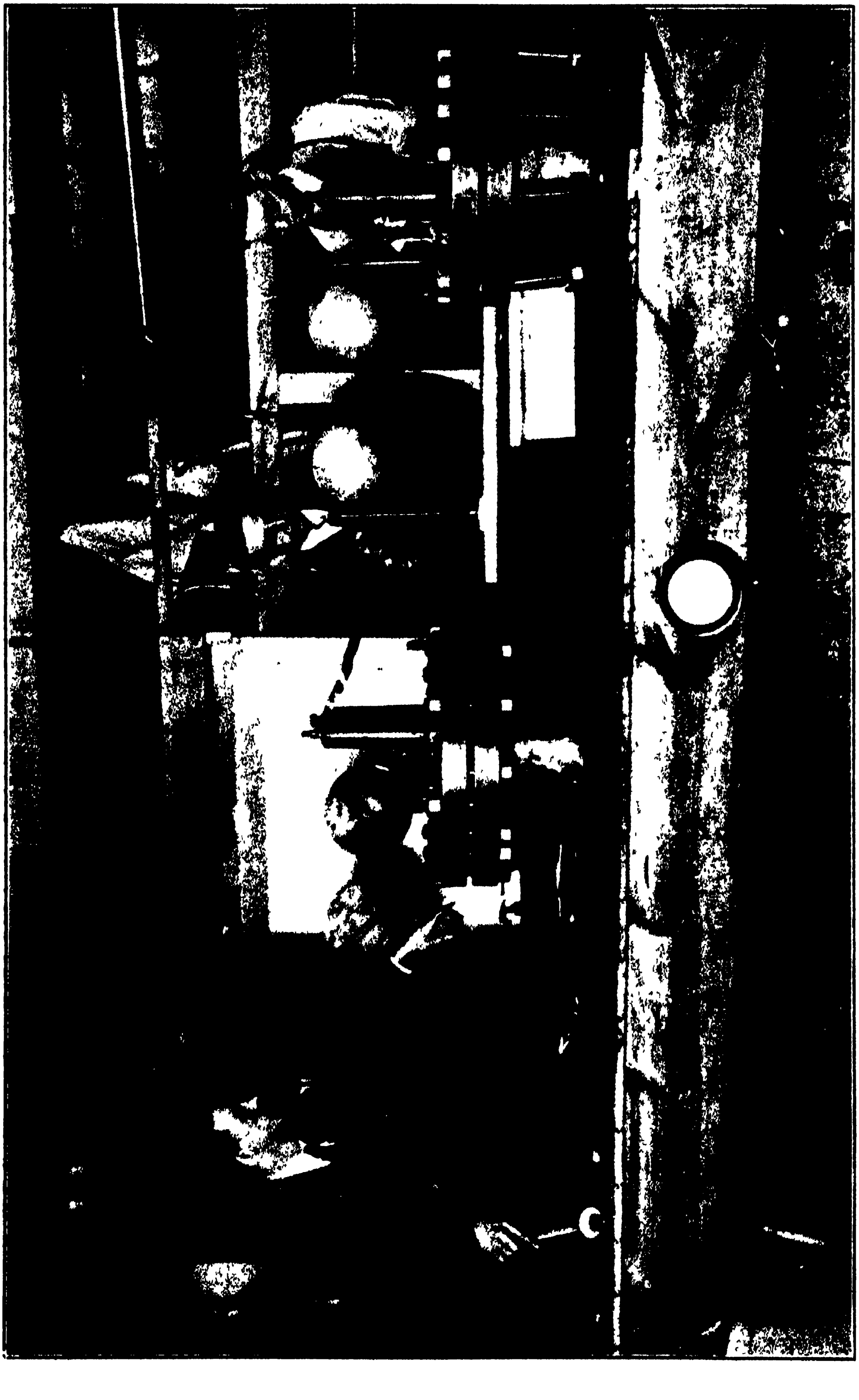
I would like to close with a quotation from a talk given by Sir William Bragg at a recent luncheon of the New York Museum of Science and Industry:

> We are linked together in one great endeavor to make the presentation of knowledge understood by the people and useful to them. That is the elemental feature. . . . As time grows and the horizon widens, we see that the first views of what science does are greater now. We are all committed to the attempt to try to bring it to the service of mankind. It is a great enterprise and we only see dimly now what can be done, but we do hope to do much. In the attempt to explore the wonders of the world, to add beauty where people did not see beauty before, we are doing something for the service of mankind.

F. C. BROWN

THE EIGHTH AWARD OF THE AMERICAN ASSOCIATION PRIZE

THE eighth award of the American Association for the Advancement of Science prize of one thousand dollars was made at Cleveland to Drs. M. A. Tuve, L. R. Hafstad and O. Dahl, of the Department of Terrestrial Magnetism, Carnegie Institution of Washington, who were joint authors of a paper entitled "Experiments with High Voltage Tubes" presented at the Cleveland meeting. This prize is awarded annually to the author of a notable contribution to the advancement of science given at the association meetings.



THE HIGH VOLTAGE TUBE AT THE CARNEGIE INSTITUTION OF WASHINGTON

Dr. M. A. Tuve (left) and Dr. L. R. Hafstad (right) and Dr. O Dahl (not shown) were the recipients of the American Association Prize.

A summary of the high-voltage work as given by Dr Tuve in his presentation of the paper at Cleveland is as follows:

(1) Using the high voltages produced by ordinary Tesla coils immersed in oil we have operated sectional high-voltage tubes to approximately 2,000,000 volts.

(2) We have made measurements of the deflections in a calibrated magnetic field of the beta rays produced by these tubes. The maximum Hρ values (the numerical measure of the deflections of the electrons in the magnetic field—Ed.) measured for these beta rays correspond in equivalent voltage to the peak voltages applied to the tube, as measured by the capacity potentiometer. This constitutes a completely independent verification of our voltage measurements.

(3) Since most of the beta- and gamma-rays from radium have voltage equivalents under 1,000,000 volts and nearly all lie under 2,000,000 volts we have artificially produced beta- and gamma rays practically covering the radium spectrum.

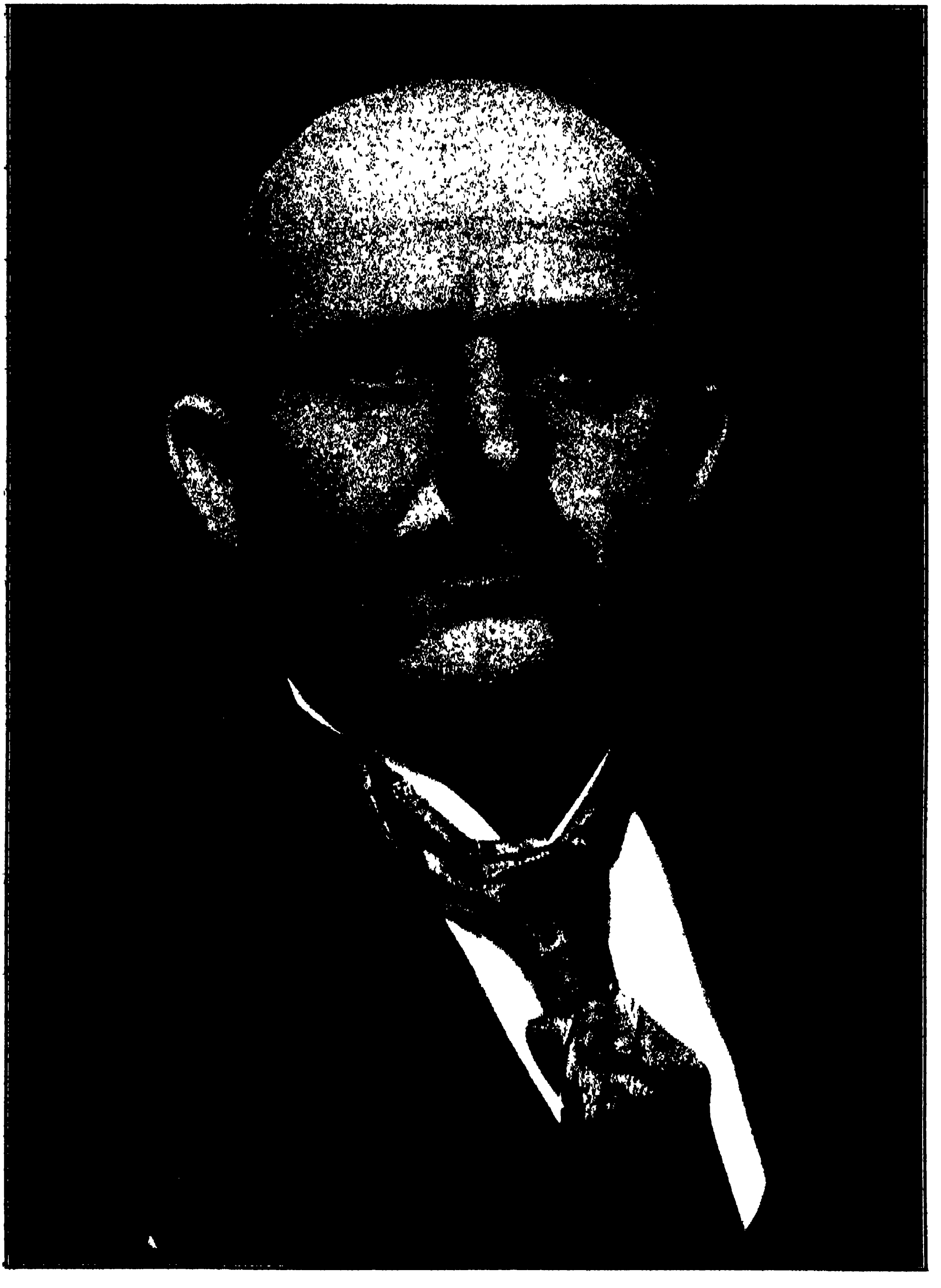
(4) We have measured the gamma-rays from the tubes through one, two and three inches of lead using a Geiger Müeller tube counter. At 1,300,000 volts peak the absorption coefficient of the gamma-rays from the tube after filtering through one inch of lead is practically the same as the absorption coefficient of the gamma-rays from radium measured on the same instrument with the same filtering.

The above statement, despite a few technical phrases, gives a reasonably understandable account of the work for which the award was made. In essence it is simply that two of the three types of rays emitted by radium, the beta-rays or very high-speed electrons, and the gamma-rays, or very penetrating x-rays, have been produced artificially in the laboratory.

The work which was reported at the Cleveland meeting had been presented two weeks previously in Washington at the annual public exhibit of research activities of the Carnegie Institution of Washington.

In the exhibit the high-voltage tube and associated apparatus with which the artificial beta-rays were produced and measured was shown, together with typical examples of the beta-ray records. Records of the gamma-rays from the tube, obtained after penetrating one, two and three inches of lead, were given, and comparison records of the beta- and gamma-rays from radium were shown to illustrate the fact that the artificial rays produced by the high-voltage tubes covered practically the complete range or spectrum of the corresponding rays from radium. One of the interesting technical features of the work was the method of "heat working" of the pyrex glass from which the tubes are constructed.

Considerable public interest has arisen in the possibility of using the gamma-rays from such tubes for the treatment of cancer, since the rays from the tubes are identical with those used in the therapeutic applications of radium. The equipment as used in these experiments produces an intensity of radiation equivalent to enormous quantities of radium but only for extremely short periods of time, the operation of the tube being intermittent. Due to the limitations of small-sized electrical equipment and to the lack of necessity for large intensities of radiation for the physical measurements, as well as the personal risk to the experimenters themselves from heavy exposures to the rays, no particular effort has been made to increase the total intensity of the radiation. This would mean simply increasing the fraction of the time which the high voltage is applied to the tube during each second of operation, thereby increasing the time-average of the intensity of the radiation from the tube. If large intensities of gamma-rays, comparable to very large amounts of radium, are desirable for medical purposes, it is, so far as can be foreseen by workers in this field, chiefly a matter of the provision of the equipment which would be required. The present equipment at the Carnegie Institution laboratory, of small power but giving a very high voltage, promises usefulness in directions related to atomic physics rather than to medicine.



DR. HANS FISCHER

THE AWARD OF THE NOBEL PRIZE IN MEDICINE TO DR. HANS FISCHER

THE question which arises in the mind of the general public—and the general public includes everybody except closely related specialists—when a scientist is extolled by the award of a Nobel Prize is, What benefit will mankind derive from the work which is thus singled out? The practical benefit, however, is not the standard of rating of scientific attainment unless the term includes the satisfaction of the curiosities of the human mind. The standard for rating a scientific work is based on the aims of the given branch of science. Chemistry is a broad science composed of many branches, each having its own tasks, each with its own history. The branch of chemistry to which the contributions of Hans Fischer belong is named "Organic Chemistry." Its aim is the study of the architecture of substances of plant or animal origin. It is one of the oldest fields of human endeavor, yet it won the rank of a rational science only in the second half of the last century when it evolved its own theory and its own aims. Until that time the contributions of organic chemistry were of an empirical character. The great contribution of organic chemistry of the nineteenth century was the evolution of theory. If the Nobel Prize had then existed, it should have been awarded to Wöhler, Dumas, Laurent and Gerhardt, Kolbe and Frankland, Cooper and Kekulé—not for work on the molecular architecture but for devising ways by which the architecture became discoverable. The possession of the theory then made it possible to proceed with the original aim of organic chemistry. Indeed, so true is the theory that for nearly three quarters of a century it led to one discovery after another which were crowned with Nobel prizes. Suffice it to mention the names of Emil Fischer in connection with the molecular structure of sugars and of uric acid; v. Beyer with the structure of indigo; Willstätter with the structure of chlorophyll; Wieland with the structure of bile acids; Windaus with the structure of cholesterol. To this list now is added the name of Hans Fischer in connection with the structure of hemoglobin.

The history of hemoglobin is a very long one. The substance was discovered in 1849 by a biologist, Leydig, who observed red crystals in venous blood examined microscopically. Later observers who prepared the crystals, not in microscopic but in considerable quantities, were sceptical as to the origin of the color and were inclined to attribute the color to a contaminating substance. In 1862 Hoppe-Seyler, having resorted to the spectroscope for the analysis of the substance, established its individuality and introduced the name "hemalglobin." Hoppe-Seyler also recognized that hemoglobin was a complex protein which could be decomposed into a colorless protein and into a component responsible for the color. In fact, the colored component had been known since 1853 when Teichmann described the blood crystals which are nothing else but the colored component of hemoglobin combined with chlorine. The function of hemoglobin in the organism is to transport to the tissues the oxygen required by them for their respiration; in other words, to permit them to develop the energy required for their respective functions. Hemoglobin, or rather its colored component, hematin, constantly undergoes decomposition and its supply constantly needs replenishing. It is calculated that every two and a half months the total hematin supply of the human organism is entirely renewed. The place of destruction of hematin is in the liver and the useless product of its decomposition is the so-called bile pigment, bilirubine. The existence of a chemical relationship

between the two substances was long known to physiologists, but the exact nature of the relationship was in need of explanation. In course of time it was found that substances related to hematin have a wide distribution in living cells of animal and plant origin and also in non-cellular tissues of all forms of life. The nearest relative of hematin is the chlorophyll present in all green plants.

Thus it is seen that the problem of the structure of hematin and related substances had engaged the interest of biologists and of chemists for a very long time and, indeed, to Willstätter the Nobel Prize had already been awarded for his contribution to the chemistry of chlorophyll and Willstätter already had suggested a theory of the structure of hematin. Kuster, in 1912, advanced a theory of structure of hematin which is not much different from the one evolved by Hans Fischer The question here again arises as to the unusual merit of the work of the latter. The answer is found in the writings of Hans Fischer himself. The colored component of hemoglobin as first crystallized has the composition $C_{34}H_{32}N_4O_4F_3Cl$, hence it consists of 76 atoms A theory of structure of the substance must represent such an arrangement of the atoms with respect to each other which expresses all its properties and all its transformations. Often, however, several closely related arrangements may express sufficiently well the properties of a substance and the selection of the true may present great difficulties. In discussing his own speculations as well as those of other workers, Hans Fischer repeatedly emphasized that the truth of the theory can be demonstrated only by synthesis and such a proof has finally been furnished by himself. To realize the magnitude of the achievement it is necessary to understand that the porphyrine (the iron and chlorine free part) of hemin consists of four pyrrolnuclei (not all of identical structure) each consisting of a ring structure containing 4 carbon atoms and 1 nitrogen. These four units are combined by links of a carbon atom into a larger ring containing in all 20 carbon atoms. The remainder of the carbon atoms, 14 in number, have to be distributed as side chains of the four pyrrolnuclei. Information as to this distribution was obtained to some extent by the process of cleavage which led to the formation of the hemapyrrol bases and hemapyrrol acids. From the theory of the structure of these fragments by speculation, the molecule of hemin has been reconstructed. Hans Fischer, however, reconstructed the molecule of hemin experimentally step by step, first contributing much to the knowledge of the pyrrolderivates, then combining two pyrrolnuclei through a carbon link into a single complex, and, furthermore, linking these complexes into such as contain the skeleton of the porphyrines consisting of a system of four pyrrolnuclei as it occurs in hemin Finally, he succeeded in producing in the laboratory hemin as it occurs in nature.

Hans Fischer began his work in 1911 with a study of bilirubine, the bile pigment, and its relationship to urobiline, the urine pigment The work was begun at the suggestion of Professor Friedrich Müller, the great clinician, whose assistant Fischer then was One could scarcely have predicted, at that time, that this modest beginning would lead to the elucidation of an extensive class of pigments occurring in all forms of life with a promise of further discoveries. It must be emphasized that ingenuity of mind and virtuosity of technique alone were not sufficient to accomplish the work of Fischer. It required, in addition, the gift of leadership and organization.

P. A. Levene

THE SCIENTIFIC MONTHLY

MARCH, 1931

MATHEMATICS AND SPECULATION

By Professor E. T. BELL
CALIFORNIA INSTITUTE OF TECHNOLOGY, PASADENA, CALIFORNIA

The rapid advancement of science is nowhere more strikingly apparent than in the numerous excellently contrived accounts of current science prepared for the scientific layman by professional scientists and by those who believe they understand what scientists are talking about in their ingenious theories. A reasonably critical mind, contemplating these brilliant expositions of fact or fascinating speculation on the apparent state, purpose and destiny of man and the universe, may become slightly confused by the subtly conflicting testimony of so many witnesses to the truth, but this is only a minor blemish on an otherwise encouraging picture of progress and universal enlightenment. The downright skeptic, looking for a light in his darkness, who closes more than one of these books or articles with the ejaculation, "God help the layman!" may be forgiven, for that help and no other is precisely what some authors abandon their readers with in their concluding chapters. And the reasonably critical mind will neither affirm nor deny, but continue to seek answers to such of its questions as seem to make sense.

Science has at last become articulate, not to say garrulous. Mathematics is not classed by some with the sciences, but this is of no importance here. What does matter is the fact that mathematics can not descend to untechnical language so readily as the sciences. Non-Euclidean geometry, with all of its deep implications for metaphysics no less than for physics, began to pass into the common stock of knowledge only with the popularity of Einstein's general relativity, long after it had been a commonplace to the geometers. Modern algebra, even now, is only beginning to influence the speculations of physical science, and the theory of algebraic numbers and ideals, of no less philosophic interest than non-Euclidean geometry, is still all but unknown outside a narrow circle of arithmeticians.

Through its scientific applications, mathematics has been heard to a slight extent, it is true, but only indirectly. The significant contribution which mathematics might make to the present wide-spread appreciation of science has not been made. The confident user of "mathematics as a tool" is but seldom, if ever, troubled by doubts concerning the sharp implement in his hands, and few suspect that it can cut both ways. The more credulous seem to be unaware that mathematics is neither the handmaiden of science nor the servant of theology, but queen of the sciences, whose subjects must learn to distinguish between credible proof and plausibility, or perish.

Most reputable physicists, I presume,

would believe that they agree with Dirac that (his italics) "*the only object of theoretical physics is to calculate results that can be compared with experiment,*" even when some of them proceed to apply theoretical physics to speculations whose very nature precludes comparison with experiment. A similar remark applies to any science speculating outside its own specialty. The speculations as a rule are of but slight interest to specialists, and only the layman, who cares little for the dry technicalities of science, is taken in.

We are all laymen and largely ignoramuses outside our own narrow specialties. In particular, the mathematician looking at physics is merely a layman, and the theoretical physicist using mathematics is in general a mathematical layman. When a scientist wants anything at all from a mathematician it is usually help with some unimportant technical difficulty, like solving differential equations or evaluating definite integrals. Seldom if ever is a mathematician invited to examine the hypotheses which produced the equations or the integrals. If by chance he should catch a glimpse of the assumptions—often quite shocking to a cautious mind—beneath the mathematics and offer any remarks, he may be advised, in the words of a typical Cambridge tutor, to cut the cackle and come to the differential equations.

Now, the scientist's cackle is precisely what interests the mathematician as a scientific layman, for the differential equations are either too easy or completely beyond his powers—usually the latter if the scientist himself can't handle them. And the complete layman, who is neither mathematician nor scientist, cares nothing for differential equations, never having seen one in the flesh. Mach's "Principles of Mechanics," with its few unobtrusive equations that can be skipped without losing a step, if one is reading chiefly for entertainment, is a much chattier and humaner book than Lamb's "Higher Mechanics," in which there is hardly an audible cackle from preface to finis. Which will the complete layman prefer? Each book fills its proper niche in a liberal education in mechanics. But a moderately clear understanding of one—I need not say which—is unlikely without a thorough mastery of the other or its equivalent. A less old-fashioned instance is offered by Eddington's two books on relativity, already classic so far as English-speaking peoples are concerned, "Space, Time and Gravitation," and the "Mathematical Theory of Relativity." Here, however, the division is less sharp, as certain passages in the two books seem to have skipped from one book to the other in their shuffle through space time.

Only when the mathematical layman and the scientific layman meet on the common grounds of speculation or hypothesis, does either believe in his heart that he can show the other anything with which he is not utterly incompetent to deal. On these debatable grounds the last word belongs as a rule to the most vociferous and the most credulous, and the interested bystander, who is neither a mathematician nor a scientist, goes away convinced that he has heard at least an echo of the eternal truth, whereas he has only been richly muddled by a loud noise. What the respective professionals suspect of being mere hypothesis, rank conjecture or baseless aspiration, although occasionally one is simple enough to deceive himself and gloss his suspicions for the benefit of the complete layman, passes for established fact in the uncritical mind which hungers to be convinced of something, no matter what.

I do not mean for a moment to imply that scientists are more addicted than mathematicians to speculation. Passage for passage, the wildest speculations of the scientists outside their own field can be matched by the like from mathema-

ticians who have endeavored to tell mathematical laymen what mathematics is and what it is all about. Less than six months ago I came across, in a serious current mathematical publication, sponsored by a reputable mathematical association, this remarkable utterance, "Mathematics is the handmaiden of Theology." To some mathematicians at least such pronouncements are improper and distasteful.

The effect of speculations on those rather shy of the meager facts beneath the alluring speculations is illustrated by the eighteenth-century story of the mathematician Euler and the philosopher Diderot. Most mathematicians doubtless know it; but as some may be unfamiliar with De Morgan's corollary (which he added only to the second version in his "Budget of Paradoxes," 1872, p. 474), I give it in abridged form.

> Diderot paid a visit to Russia at the invitation of Catherine the Second. At the time he was an atheist, or at least talked atheism: it would be easy to prove him either one thing or the other from his writings. . . . A plot was contrived. The scorner was informed that an eminent mathematician had an algebraic proof of the existence of God, which he would communicate to the whole Court, if agreeable Diderot gladly consented . . . (Euler) came to Diderot with the gravest air, and in a tone of perfect conviction said, "Monsieur! $(a+b^n)/n=x$; donc Dieu existe; répondez!" Diderot, to whom algebra was Hebrew . . . , was disconcerted; while peals of laughter sounded on all sides. Next day he asked permission to return to France, which was granted.

Now for De Morgan's corollary. "An algebraist would have turned the tables completely, by saying, 'Monsieur! vous savez bien que votre raisonnement demande le développement de x suivant les puissances entières de n'.'" I imagine some mathematicians will sympathize with Diderot when confounded by new epistemologies, bizarre eschatologies and budding theologies hurled at their bare heads by the unscientific prophets of current scientific speculations. The worst of it is that even the wildest speculations may be right for all that any helpless mathematician knows. Perhaps the best answer to the more bewildering conclusions of the prophets is to adopt De Morgan's suggestion, and demand that our tormentors express all their probabilities as cube roots of quaternions, in order to avoid the pitfalls of the excluded middle and so attain the necessary pitch of modern mathematical rigor.[1]

2. The signal contribution which mathematics might make to the ever-widening dissemination of scientific ideas is a sharpening of the critical faculties and a deepening of intuitive insight. This could be accomplished, at least in part, by making accessible to those who are not professional mathematicians the profound disturbances of this generation and the one just past which have shaken to its very foundations the entire vast fabric of modern mathematics. The fundamental concepts involved, and

[1] By a singularly beautiful freak of irony this outrageous demand was not met, but was surpassed and then met a week after it was written. Proca (*Journal de Physique et le Radium*, (7), 1, No. 7, July, 1930, p. 247) interprets the psi function in Dirac's equation as a *quadri* quaternion, whose 16 components are hypercomplex probabilities in his $(3+1+1)$-dimensional space-time-matter world. These "quaternions of quaternions" (a Clifford linear associative algebra in 16 units with a modulus) are quantum probabilities. The author commends to mathematicians the problems thus created by his concept of *hypercomplex probabilities* It is to be hoped that no mystic from his dimensionless world interprets this as a challenge from our $(3+1+1+1)$-dimensional world of space-time-matter-sense; (as a [illegible] the new quantum probability universe seems to lack a dimension). For if, as some eminent scientists have recently informed laymen, the current non-imaginary probability interpretation of quantum mechanics reveals a Supreme Being, how many such Beings are revealed by quantum mechanics as a *sixteen-fold imaginary system of probabilities?* Does not Proca's perfectly good and extremely interesting exercise in formal algebra reduce all such speculations to the level of Euler's refutation of Diderot, that is, to unseemly jests?

the language in which they are described, should present but few difficulties to a generation which has learned the patter of relativity and the metaphors of quantum mechanics. Indeed, in the whole discussion there is nothing so knotty as a curved space time, and little so slippery as the quantum hypothesis of uncertainty or indeterminacy, both of which are profoundly modifying thought outside their own scientific domains. The disputed points in the foundations of mathematics are in fact far simpler in appearance, and no less deceptively easy of apprehension, than most of the basic abstractions from which current physical speculation proceeds.

To this program one type of scientist will raise immediate objection. It is an old, old objection. Science is not mathematics. Most mathematicians are now aware of the fact. And they know also that mathematicians are often taxed with demanding proof in the strictest mathematical sense where it is absurd to demand such proof. They are also accused of haggling over straws when the haystack is on fire, and splitting hairs to splice a cable when the bridge is about to be washed out.

The classical instance is that of Laplace, who also had some claims in his day to be counted among the scientists Napoleon Bonaparte, that eminently practical man, declared that this great mathematician failed as an administrator because he sought subtleties everywhere, and carried into politics the spirit of the infinitesimal calculus. This remarkable verdict was inspired in part by Napoleon's desire to oust Laplace in order to provide a profitable job for a nephew, who carried no sort of *esprit* into politics or anything else. Its injustice is evident from the most cursory inspection of Laplace's career. As a mathematician he did mathematics; as a politician he did politics, and did it in a style suited to his patron and his times. The mathematician Cauchy also showed himself to be a practical politician of no mean proportions. And several mathematicians have been philosophers, or even scientists, of parts.

Whatever truth there may be in the general charge scarcely concerns us here, for the matters in dispute are simple, common to all consistent thinking and not obscured by any doubts as to the desired object. If it were ever true that to a pure mathematician all things are pure mathematics, it is no longer so. With the discovery of the past thirty years that mathematics is less pure than some mathematicians thought it, being contaminated by psychology, metaphysics and all sorts of other enticing impurities which some purists would like to boil off, the bigoted search for purity where it does not exist has ceased. It is precisely because many mathematicians have come to realize that nothing is so uncertain as seeming certainty, unless it be apparent uncertainty, that some of them hesitate to accept as worthy of serious human consideration the speculative conclusions of science outside of its own inhuman province.

On the debatable ground we are all laymen, pure and simple, and if the experience of mathematics means anything for science the conclusion of the whole matter is to be cautious—more cautious than any speculative presentation of current science would have us be. With the speculators in this connection may be classed those specialists who, in serious treatises, proceed to epistemological conclusions in apparent disregard of everything that has been done in the past thirty years in the foundations of logic and mathematics, and who seem to believe that every one understands what probability means when applied to the actual world.

3. When a scientist tries to jar a

mathematician by boasting that he uses one theory on the even-numbered days of the week and an apparently contradictory one for the same phenomena on the odd days, he is disappointed when he fails. Frequently the scientist confesses a desire to reconcile his theories, and sometimes he succeeds brilliantly, as for instance with his waves and corpuscles. For twenty years or more mathematicians have been beating this poor showing of the scientists. It is a hopelessly antiquated mathematician who can not dispute the consistency of his fundamental assumptions while using the analysis deduced from them to establish theorems which one compartment of his mind believes to be true, while the adjacent compartment believes them to be not false but mystical nonsense. The last is merely the rather brutal characterization which some doubters, not content with half-way compromises, assign to ideal theorems in the technical sense of the thoroughgoing formalists.

Mathematical speculation, it would seem, can meet scientific speculation on terms a little better than equal. Unfortunately the two have not yet met in public, and scarcely at all in private. When they do meet, if ever, we may look for the most clarifying session in the history of human thought. And, if a prediction may be ventured, both participants in that shattering debate and all those fortunate enough to hear it will rise with considerably fewer convictions than encumbered them when they sat down. This, however, need not be taken seriously by any who cherish their present prejudices, for an example will be given later to illustrate the utter folly of most predictions concerning the futures of mathematics and logic.

Let us imagine for a moment that mathematical speculation and its younger scientific sister do meet to discuss their perplexities, and that they retain sufficient poise to conceal their mutual disrespect. What, if anything, may either hope to learn from the other? From a dispassionate examination of her younger sister's effects, mathematics may conclude that unlimited publicity is not such a bad investment after all, and that a touch of humanity of the proper color now and then improves the general appearance and adds to the joy of living. The younger, impressed by the calm assurance of the other, after a life of disillusionments, may foresee her own future, and silently agree that no bread is better than half a loaf when the whole is moldy and ripe with weevils. In the meantime she will have her fling, and in the end attain the imperturable serenity of her older sister, secure against all assaults of doubt, for she will have outgrown her adolescent ambition to rule society and the universe.

The above sketch may be unduly optimistic. There is little evidence to show that one clan can profit by the mistakes of its neighbors. Each goes its own way and learns, if at all, by experience. It may be useless to point out that mathematical speculation found it self-destructive to read into the conclusions of mathematics more than was given unequivocally by the strictest techniques of mathematics alone, subject to incessant examination and merciless criticism to detect concealed assumptions and flagrant contradictions. It may be a waste of time to recall that the simplest and most obvious of all the sciences has not yet agreed with itself as to what is provable, what not provable, what is sense, what nonsense, and what the provinces of meaning and inference are for the most rudimentary abstractions of which the reasoning mind has thus far shown itself capable. Unbridled speculation may not be checked by the history of any of the intellectual disasters to which it has led.

But surely the average intelligent human being will be moved to a little healthy hesitation in accepting the more preposterous inferences drawn by enthusiastic prophets of current scientific speculation when he suspects that even mathematics can not deduce sense from ill-understood concepts or from insufficient hypotheses. He may even begin to suspect that not every lame duck he sees is a swan.

Not even the most critical onlooker would presume to object to any purely scientific hypothesis or speculation which science may find convenient for scientific purposes. It is only when speculative solutions for age-old human or philosophical problems, which may not even have been properly put for all that any one knows, are confidently advanced in the name of science as worthy of human consideration that protest becomes relevant. Scientists themselves have objected in the past to unwarranted appropriations of their workaday stock in trade, and if they do not object now it may be because they have grown indifferent. Some who are merely scientific laymen feel, however, that the broadcasting of speculation has gone too far to be wisely ignored.

4. Anatomizing defunct speculations may not be a very clean pursuit, but it can occasionally indicate that some of the living are less healthy than they might be and show what is likely to kill them. Unless he were told the year in which the following alleged demonstration was put forth in a serious book which had a tremendous sale, an unsuspecting mathematician might well swallow it whole for a brilliant speculation fathered by current science. The occurrence of two ethers in the theory need not perturb a modern reader. Some physicists still find it convenient to speak in terms of an ether even when discussing relativity, and they do so with full knowledge and perfect propriety. So let the innocent mathematician, who is only a layman in speculations outside his own, plunge into this with complete confidence that he is in reputable company.

Matter is made up of molecules (size A), which are vortex-rings composed of luminiferous ether. The luminiferous ether itself is made up of much smaller molecules (size B), which are vortex rings in a second or subether. Call these smaller molecules and the sub-ether in which they are embedded the Unseen Universe. The human soul exists in the Unseen Universe. It is made of the smaller molecules (size B). In life it permeates the body like a subtile gas. The thoughts we think in life are accompanied by vibratory motions of the molecules (size A) of the brain. These motions undulate through the material universe. But, by the conservation of energy, part of these motions will be absorbed by the molecules (size B) of the soul. Therefore the soul has memory. On the dissolution of the body the soul with its memory intact becomes a free agent in the sub-ether. The physical possibility of the immortality of the soul is thus demonstrated.

It sounds like sense, but is it?

"The Unseen Universe" was not written by Euler in the eighteenth century. Nor was it intended as a satire for mathematicians and other scientific laymen. If I have done an injustice in the above rough, secondhand paraphrase—it is not too rough—to the distinguished scientists who made the "Unseen Universe" a best seller, I apologize to their sub-molecular molecules wherever they may be in their sub-ethereal ether. Turning to the title page we see the names of the distinguished British physicists, Tait and Stewart (the book was first published anonymously). It seems incredible that the same Tait could have collaborated with Lord Kelvin in the great "Treatise on Natural Philosophy," but possibly the influence of Kelvin (who was a devout Christian and who hated unwarranted speculation as violently as he once hated quaternions) kept the sub-ether out of the treatise. And it is little short of a

miracle that some practical joker has not gone Euler one better by erasing the date, 1875, and offering the all but forgotten classic to some book of the month club. It sold by the ton lot once; why not again? So far as mathematicians and reasonable human beings were concerned, the "Unseen Universe" was smashed flat by the mathematician Clifford. His essay on the subject still makes amusing reading, particularly for his own shrewd speculation which foreshadowed an essential part of general relativity.

5. To some readers of Eddington's "Nature of the Physical World" (1928), one of the best things in it is a sentence on the last page. "The religious reader may well be content that I have not offered him a God revealed by the quantum theory, and therefore liable to be swept away in the next scientific revolution."[2] The irreligious reader may perhaps regret the omission. And the mere mathematician, always in his humble status of scientific layman, will accept without question the dictum that "In a world of aether and electrons we might perhaps encounter *nonsense;* we could not encounter *damned* nonsense."[2] For to at least some mathematicians certain extra-scientific speculations foisted onto the science of 1930 seem to come perilously near to the second kind of nonsense and to be no better than the "Unseen Universe" of 1875.

It is all to the greater glory of mathematics to admit that we are *not* living in a world of "aether and electrons," but rather in a gorgeous muddle of tensors, wave-equations, q-numbers, Hilbert space and Hermitian matrices. Mathematicians as professionals are familiar enough with these things to regard them with indifference; what interests the mathematician as a scientific layman is the question of what all these notations mean in reference to the actual world.

The answer that they are meant to mean nothing has been given. If that is all there is to it, many of us will be content. But is it the whole story? I think not, and I base my opinion on certain of the questions which scientific speculation propounds and talks about in books which are unmistakably serious and which make very heavy reading. Incidentally, one of the amazing things which impresses seasoned mathematicians trying to follow afar the recent developments of theoretical physics is the facile skill with which young men scarcely out of their teens handle the tricks of the mathematical game like masters. It makes Abel and Galois more real to us, and we can believe that such men actually lived a century ago.

After following as best one can some of the more speculative parts of the new theories, one need not stretch the imagination to frame the sort of question the candidate for a lay degree in modern theories may be expected to answer in 1931 unless something pretty drastic happens to our understanding of the famous uncertainty principle between now and then. Here is a specimen, frankensteined from a vivisection of the sole survivors from the destruction of the "Unseen Universe."

> From the spinning electron, Heisenberg's uncertainty principle and the most recent attempts with which you are familiar to quantize relativity and relativize quanta, deduce consciousness, the freedom of the will and the existence of nonsense and hence show that an introverted mysticism is not incompatible with the good life, however well defined and however badly lived.

To this inhuman question the humane examiner may add a footnote, recalling what the uncertainty principle is (or

[2] A. S. Eddington, "The Nature of the Physical World." By permission of The Macmillan Company, New York, publishers.

was in 1928). The following simple description for laymen is due to Professor Eddington.[3]

> Suppose that (ideally) an electron is observed under a powerful microscope in order to determine its position with great accuracy. For it to be seen at all it must be illuminated and scatter light to reach the eye. The least it can scatter is one quantum. In scattering this it receives from the light a kick of unpredictable amount; we can only state the respective probabilities of kicks of different amounts. . . . if the kick is small the probable error will be small.

The short mathematical statement may be found in any one of numerous recent treatises. It need not concern us here. Like the foregoing, all involve the notion of probability or of a statistical measure in the mathematical senses as commonly applied by orthodox scientists. This point is the only one of interest to critical mathematicians.

Those who find difficulty in visualizing the probabilities of quantum mechanics may be helped by the ingenious interpretation of Schrodinger's psi function as an imaginary probability.[4] It really is quite simple; starting from Borel's concept of probability as a certain real arithmetic in the interval 0 to 1, the mathematician may proceed to resolve any number in the interval into a pair of conjugate complex numbers. Schrodinger's psi multiplied by its conjugate is usually interpreted as a probability. Hence Schrodinger's wave equation describes the distribution in real space and time of imaginary probabilities. The possibilities thus introduced for hyperscientific epistemology are unlimited.

Now, no scientific layman has a right to object to any inductions from the uncertainty principle within its own domain. But what are mathematicians and other mere laymen to think of the devastating generalizations inferred from the principle outside the region of physical science? For example, it is an interesting current speculation that strict causality is rendered meaningless and that all the philosophical implications of determinism are abolished by the principle. But are they? Doubtless many mathematicians as well as other laymen would be glad to see the last of all obscure speculations, materialistic or idealistic, deterministic or indeterministic. They may be disappointed if they expect the uncertainty principle to do their housecleaning. For it all depends upon the meaning of one word, probability. On this point there seems to be considerable haziness, which is perhaps even a more hopeless situation than a sharp division of opinion.

My own belief, for what it may be worth, is that these extra-scientific inferences from the principle can not tarry "to be swept away in the next scientific revolution." I believe that they have already been swept away, as mere straws on the general flood, in the present mathematical revolution, which has been in full tide for a generation and is still going strong. They have therefore already attained that unblessed state which Eddington calls "damned nonsense." However, this is merely a personal opinion, liable to be swept away in the next mathematical revolution.

6. That equally competent experts should disagree on the meaning of probability seems a sufficient reason that the inexpert should suspend judgment on the wider speculations originating in the quantum uncertainty principle. There is of course no doubt as to the "meaning" of the formal definitions in the text-books on probability or least squares. For the most part they are so trivial that even beginners can apply

[3] A. S. Eddington, "The Nature of the Physical World." By permission of The Macmillan Company, New York, publishers.

[4] Proca, "Mathematica," 1, p. 22, 1929.

them with ease to problems on games of chance few of them have ever played.

What is in dispute is the step from the purely mathematical definitions to their applications to the actual world. If one set of opinions regarding the meaning of probability should turn out to be right, then all the wishful abolitions of superfluous philosophies will be justified. Should the same set of opinions turn out to be wrong or inadequate, the position will be one of stalemate, and for all of any one's desire to get rid of certain speculative systems of the past we shall still have them with us.

Probability and what comes out of it beget innumerable instances of the kind of mathematical precision which exasperates the confident user of "mathematics as a tool" into calling all mathematicians who are more than animated calculating machines vain quibblers. The dishonorable "mathematics is the handmaiden of science" tradition also shows up here in all its shabby splendor.

For example, any genial expert on thermodynamics will expound the meaning, not only of probability, but of its logarithm to any doubting or obtuse mathematician. The mysterious logarithm takes on the minatory semblance of a time arrow, and the mathematician hears the death rattle of the universe as it runs down like a rusty and worn-out alarm clock. The time arrow, carefully avoiding the circular points at infinity, is never perpendicular to itself; the entropy increases monotonously to its proper maximum, and the frozen mathematician awakes in a very cold sweat indeed, to find himself flat on his back on the void floor of absolute zero. Awakening from his nightmare he is informed that, if not damned, he is lucky to be alive in this brightest and best of all possible universes in this best of all possible times. Muttering that this singular conclusion is extremely improbable (its "probability" is the limit of one divided by a number that tends to infinity), the mathematician departs to think over exactly what it was that the scientist did to him. But he is alone and without solace, for the handmaiden fled to drown herself in the kitchen sink when her employer began the pragmatic part of his demonstration.

It ran as follows: "My hypothesis is true because it works. The hypothesis was P. Now P implies my proposition Q, as can be verified both mathematically and experimentally. But Q is known to be true. Therefore P is true. Now again, P implies R, as can be shown mathematically and verified experimentally. Therefore, since P is true, so also is R."

To which the bewildered mathematician might reply, "Why go to all that bother to 'prove' that R is true? Wouldn't it be simpler and much shorter to substitute a false proposition F for P at the beginning? Then you could get the whole alphabet at one clattering swoop instead of your single R, for a false proposition implies any proposition you like. It is no trick at all to square the circle by this method."

If this is a travesty of legitimate reasoning with probabilities in the strict and unromantic domain of statistical mechanics, what of the epistemological and humanistic parodies of the quantum uncertainty principle put forth by some of its more daring interpreters to impress imaginative laymen? Is either kind of travesty more far-fetched, nonsensical and absurd than the other? If you think so, consider Whitehead's query in a similar connection: "What is the sense of talking about a mechanical explanation when you do not know what you mean by mechanics?" Then, if you find sense where Whitehead seems to find none, and still think one travesty more sensible than another, you are the only layman living who will admit that

he understands the speculative, extra-physical applications of quantum mechanics to their last h.

7. Even a critical mathematician will grant that a theoretiker is within his rights when he imagines his swarms of particles distributed in any way he pleases in their neat pigeonholes in space of the proper number of dimensions. Mathematicians themselves have been doing similar tricks with variously colored balls and urns since the time of Fermat and Pascal. But it is only a very naïve and unsophisticated mathematician who believes that his amusing game has yet been proved to mean anything essentially more profound than juggling with the proper fractions deposited by a suspiciously prolific definition. A cautious juggler would hesitate long before admitting that he knew—if he thought he did—what is meant by the phrases "random distribution," "random sample" and "equally likely." Without a clear understanding of what these elementary things mean in relation to inferences concerning the actual world, it is difficult to see how inductions from statistical theories can make any significant contribution to epistemology, or even to theoretical physics as distinguished from mere algebra and arithmetic.

The newer theories have gone far beyond the elementary notions of mathematical probability. The very questions which it would be of supreme interest to answer appear to be presupposed in a hopeless tangle of inexplicit postulates, ambiguities where precision is essential, and elementary mathematical processes of the game of probability; and the final outcome beyond the algebra and arithmetic appears as a vicious circularity so far as epistemology is concerned.

To all this the confident scientific user of probability replies that the pragmatic test suffices; the theory works. It predicts quantitative results that can be checked by experiment. This merely emphasizes the question. Why does the theory work? And why has the Gaussian or any other statistical law of error anything at all to do with the actual world? Some scientists would say that the questions are meaningless; others are bolder, and point to their epistemological conclusions as the answer, believing that they have not begged the question. Does not this suggest that such speculations are beyond the present range of science and not to its credit? In any event it is pretty certain that the pragmatic answer is not that which the layman, interested in such things, believes he is getting when presented with one in the name of science. And the step from purely scientific or mathematical applications of the ill-understood concepts of probability to the profound and possibly meaningless riddles that have plagued human thought for centuries is so vast that more than the seven-leagued boots of science are called for to take it.

Any attempt at the present time to stride over the real difficulties of probability to easy and impressive conquests outside its scientific territory are to some minds as repugnant and as improper a use of scientific method as was ever imagined. To such minds the epistemological and other extra-scientific speculations, originating in the quantum uncertainty principle, are on a par with Pascal's wager. If any modern interpreter of science to the layman has forgotten that infamous misuse of purely mathematical reasoning by one of the founders of the theory of probability, let us briefly recall it.

"As the value (say v) of eternal happiness must be infinite," according to Pascal, "then, even if the probability (say p) of ensuring eternal happiness by a religious life be very small, the expectation (which is p times v, and is the

usual basis for computing the price of lottery tickets) must still be great enough to make it worth while to be religious."

For nearly 300 years Pascal's bet against the devil has stood as the unchallenged record of bad taste in speculation. It also is a fair sample of the ridiculous authority which mathematics was once wont to claim in regions where it knew nothing. Reputable mathematics outgrew this sort of thing long ago. The scientific speculations of the popularizers still seem to be tempted by the abomination.

All these doubts concerning the significance (if any) of probability as applied to the actual world may be removed tomorrow. The meaning of probability as something more than a byplay of the intricate mathematical game may be cleared up overnight. Even now some mathematicians would say that there are no doubts. To them the whole situation is clear, including the long controverted status of inverse probabilities.

Some of us will recall the amused contempt with which the investigations of Keynes, in 1921, on probability were received by some hard-headed professional mathematicians, expert in the theories of probability and statistics. Those investigations were a serious attempt to state some of the real difficulties competently and to break away from the algebraic trivialities which are sometimes mistaken for the theory of probability. That the effort was in part abortive was only to be expected from the nature of the problem, and the more recent work of Nicod bears out the critics to a certain extent, but not for the reasons they assigned.

It can not be too strongly emphasized that these subtle questions considered by the logicians of mathematics are precisely those which must be settled before epistemological or hazier speculations founded on probability as used in physics are more than a waste of time. The mere arithmetic and algebra of the situation are not in dispute and never have been since the infancy of the theory. Some mathematicians dismiss the difficulties with the epithet "metaphysics." These overlook the disconcerting fact that much of classical analysis has been forced into intimacy with what many orthodox mathematicians only thirty years ago would have branded as metaphysics, and pretty wild metaphysics at that. Kelvin's compliment that "Mathematics is the only good metaphysics" seems to be coming true, but turned inside out, as it were, with a strong reverse English.

Other experts, equally competent, profess to see difficulties in the very beginnings of the theory of probability as great as those surrounding the notorious axiom of choice. Problems in the foundations of mathematics, no more difficult in appearance than those connected with probability, have defied precise formulation, to say nothing of solution, for more than a generation, in spite of all the efforts of some of the ablest mathematicians and subtlest logicians the world has ever known, to compass them. What is the human value of speculations founded on quicksand?

Probability, as Russell recently remarked (I quote from memory) is the most important notion before the scientific public to-day. Laplace in his day said the same. And nobody, Russell added, has the slightest idea what it means.

Many mathematicians will agree with that verdict. Many scientists, as I know at first hand, will see in it only the critical mathematician's alleged propensity to quibble over the obvious judgments of common sense. The layman who looks at mathematics from the outside is free to take his choice. If he

is gifted with uncommon sense, he may suspect that common sense is not the ultimate tribunal before which such questions must be tried. In the meantime he may accept a Scotch verdict of "not proven," and speculate to his soul's content and the creeping paralysis of his critical faculties, for no one on earth can *prove* that he is wrong.

8. A common and engaging trait of the truly eminent scientist is his frequent confession of how little he knows. A critical mathematician trying humbly to understand the works of some of the greatest scientists is sometimes moved to an opposite estimate. They know altogether too much.

Instead of the copybook aphorism often ascribed to Laplace as his last utterance, "Ce que nous connaissons est peu de chose; ce que nous ignorons est immense," what he really did say is nearer the mark as some critical mathematicians think they see it, "L'homme ne poursuit que des chimères." It is almost as if the great scientist-mathematician had carefully rehearsed the first with the scientific part of his personality, only to be tricked by the irrepressible mathematician in him blurting out the truth at the most awkward moment of his life. He never spoke again.

If the scientist is modest, at least one school of mathematicians does not lack self-confidence. "In mathematics there is no ignoramibus," according to the leader of the formalists. From its context this seems to mean that all mathematical problems can be unambiguously stated and that solutions exist, but as I am not sure of the meaning I shall not press this interpretation. Possibly it conceals a definition of mathematics: "That of which we can assert that we shall not always be in the dark as to its meaning is mathematics." Having heard itself described as anything from art to symbolic logic, mathematics can survive any finite number of definitions.

Whether the problems of mathematics have been well posed, and if so whether solutions exist in any sense on which mathematicians can agree, seem to be questions for the future to decide or ignore. Experience has taught most mathematicians that much that looks solid and satisfactory to one mathematical generation stands a fair chance of dissolving into cobwebs under the steadier scrutiny of the next.

This is a different thing from the honest humility of the scientist, who foresees a possible end of his purely scientific speculations in the beginnings of others equally transitory. The bedrock beneath his dreams, the average scientist seems to believe, will stand unshaken under the hurricanes that blow away his airy palaces. What is incredible to a thoroughly critical mind viewing the wreckage of successive mathematical systems is that any one should yet believe in the existence of the bedrock.

Critical mathematicians have delved so deeply into the foundations of their rudimentary science without yet striking anything that any significant fraction of them all agree is bedrock, that they may be excused for disbelieving that others with clumsier shovels and blunter drills have got much below the deceptive surface of appearances. Like the most sanguine scientist, many a mathematician believes implicitly that the bedrock is there if only he could get through the quicksands, but the belief is not shared by all. The very existence of a reasonable doubt would seem to be a sufficient reason for boasting, not that we know so little, but that we know nothing.

In contrast to the modest assurance of the scientist, I believe (in spite of the formalists who, according to some critical logicians, have misunderstood the

nature of the issue) that it is not too strong to say that, on the things which really matter to them, mathematicians are reduced to taking their choice from among the members of that hoary and unholy trinity, ignorance, dogmatism and crass belief. Knowledge in any sense of a reasonably common agreement on the fundamentals of mathematics seems to be non-existent. Or, to put it another way, knowledge has become a function of belief; the more a mathematician believes (without proof) the more he thinks he knows.

It would be possible to arrange the eminent mathematicians of the present time into a sort of spectrum. The infra-red had better be left undescribed. The red end is complete skepticism toward the validity of mathematical reasoning. It shades gradually to a cool and comfortable green of utter indifference to everything but the merry antics of the problem-solvers, deepening into the beautiful blue of those who suspect that all is not as it should be with the green, but who believe that in the end they, and even the infra-red, will be purified into an ethereal violet. The violet is Cantor's paradise, the only genuine mathematics since the Greeks, according to W. H. Young, from which, as Hilbert has roundly declared, no one shall ever chase any one else. Beyond the violet stretch the illimitable regions of the ultra-violet, comprising all those who believe that the red and the infra-red are the unnatural offspring of forbidden quantum states, and that any who merely believe in the existence of the obscene progeny should be skinned alive and boiled in aqua regia.

That the controversies between one end of the mathematical spectrum and the other are real enough is evident from the considerable heat experienced as one passes along it in the improper direction. If they have done nothing else, recent disputes have abolished the stupid, stuffed-shirt tradition that mathematics stands coldly aloof from all human animosities. This is a healthy symptom, for it shows that neither mathematics nor the average eminent mathematician is yet perfect, and therefore that both are still alive.

Some such arrangement of mathematicians of the past half-century, with quotations from their works, should do more to destroy a degrading taste for obscure and profitless speculation than a whole library of second-hand opinions. I believe it should be made, with a minimum of critical apparatus to clarify the technical terms, and distributed at cost to all those who care to keep a balanced mind. There should be no injection of personal opinion on the part of the compiler as to who is wrong and who is right. The bald exhibition of the facts should suffice to establish the one point of human significance, namely, that equally competent experts have disagreed and do now disagree on the simplest aspects of any reasoning which makes the slightest claim, implicit or explicit, to universality, generality, or cogency. There is but little question here of wide philosophical horizons. Many of the doubts concern such elementary things as the meaning of twice two equals four.

The last will doubtless raise a smile on the face of more than one scientist—should any happen to see it. Before passing to a few extremely simple examples to illustrate our changed outlook on the scope and validity of mathematical reasoning, I should like to state why I believe that some scientists are superior to some mathematicians in their ability to see two facts where none has yet been proved to exist. I recently heard Bertrand Russell somewhat rashly confide to an audience of scientists that he felt less confident than they of some things because he had tried for ten years, and failed, to prove

that twice two is four. This was perhaps only a picturesque way of stating that the all-essential proof of the consistency of mathematics is not forthcoming from "Principia Mathematica"—the defect which Hilbert and the formalist school are endeavoring to supply with their theory of demonstration, if the intuitionists will let them. Anyway, Russell's confession was received with a roar of laughter, and after the lecture several expressed the opinion that Russell's is the example *par excellence* of a brilliant mind seduced by its own subtlety. It will take a sharper implement than Occam's razor to shave these hairy logicians.

9. All shades of skepticism and belief as to the existence and quality of mathematical truth are to be found in the current literature of or about mathematics. At one extreme is the view of one school of psychologists that the profoundest truths of mathematics are nothing more than complicated motions of the human larynx, akin to the reflex swallowing of superfluous saliva. Midway is the innocent assertion of some mathematicians that mathematics is art. To me this is particularly exasperating, as I once spent a vacation near Carmel. If nothing else, in view of the controversies between intuitionists and formalists, the art theory of mathematics is so devilishly like the apparent truth as to be unkind. At the other extreme is the speculation that mathematics is true because of Platonic idealism.

The last in one form or another has been orthodox mathematical dogma for centuries, and it still claims its eminent devotees by the dozen. Many of course find it as repugnant as the saliva theory of mathematical truth. Unfortunately, the only middle ground possible seems to be the singularly barren and uninviting desert where mathematics as such is divorced from its meaning, if it has any, and all of the interesting questions which a mere human being would like to ask *about* mathematics or its meaning are pitched into the limbo of metamathematics, a region at present as nebulous as Tartarus. Who but a confirmed juggler with symbols really cares anything about the hen track theory which reduces all mathematics to meaningless marks on dust or paper?

The answer of course is that some of the most eminent mathematicians living do take precisely that view and, quite disconcertingly, do seem to care for it tremendously. Some of us would scarcely blame the mathematical layman for feeling unsympathetic to this particular conclusion of one school of experts, but no one apparently has yet succeeded in demolishing the theory or demonstrating its irrelevance. If one takes refuge with the intuitionists, he is likely to be baffled by his inability to understand what they are talking about. At least some competent mathematicians have so expressed themselves. Here again the verdict is "not proven."

What was called above the Platonic view of mathematics (merely for brevity; there may be no foundation for it in Plato's philosophy) is seen in one of its extreme modern forms in the following quotation from a mathematical layman (Everett, 1870):

> In the pure mathematics we contemplate absolute truths, which existed in the divine mind before the morning stars sang together, and which will continue to exist there when the last of their radiant host shall have fallen from heaven. They existed not merely in metaphysical possibility, but in the actual contemplation of the supreme reason.

According to this theory, mathematicians do not *invent* mathematical theorems; they *discover* them.

One of the great surprises of my life was to find that two of the most eminent

mathematicians of this or of any age believe the Platonic theory in its uncompromising entirety. After such a shock as that I was ready to believe that all the undevout astronomers I know are madder than Nebuchadnezzar ever was. It is only fair to add the conclusion of the episode for the comfort of those who can not believe the Platonic theory. In a debate between the two mathematicians in question, in which the topic of discussion was the Platonic theory, the argument came to a sudden and disastrous end when each, as if at a preconcerted signal, hurled at the other the epithet "theologian!"

An interesting side-light on the respective leanings of those who believe the Platonic theory and of others to whom it is meaningless, appeared in a recent examination (with which I had nothing to do) given to about 300 students of science, mathematics and engineering. They were asked, "Were the theorems of elementary geometry which you studied in high school invented or were they discovered?" To a man the future scientists and engineers answered "invented." The intending mathematicians unanimously voted "discovered." Perhaps the correct answer is that silly questions are unanswerable.

A more modern variant (1928) of the theory emerges from the writings of one of the many working mathematicians to whom formalism does not seem to promise an escape from our serious mathematical difficulties.

It concerns the as yet (1930) unproved conjecture of the eighteenth-century mathematician Goldbach that every even number is the sum of two primes; thus, $8=3+5$, $24=11+13$, etc. More broadly, the doubt is about "real" propositions.

I (Hardy) ask them, finally, whether there is anything in the proposition, as relevant to logic and as Wittgenstein seems to conceive it, which affords any justification for my belief in 'real' propositions, my invincible feeling that, if Littlewood and I both believe Goldbach's theorem, then there is something, and that the same something, in which we both believe, and that that same something will remain the same something when each of us is dead and when succeeding generations of more skilful mathematicians have proved our belief to be right or wrong. I hoped to find support for such a view when I read . . . when I read further, both in the book itself (Wittgenstein's "Tractatus Logico-Philosophicus") and in what Russell says about it, I concluded I had been deceived. . . . So here I can find no support for my belief, and if not here where am I likely to find it? Yet my last remark must be that I am still convinced that it is true.

That is also the conviction of many working mathematicians. Anyhow, whether they believe in the theory of mathematical truth to which their belief in a particular "ideal theorem" commits them, or whether they boldly ignore any doubts which may ultimately nullify their conclusions, they keep on working. If the theory itself has not yet been made to work, it has the undeniable merit of making scores of productive mathematicians work who might otherwise give up in despair. Skepticism, however, is not necessarily a damper on creative work, whatever those who dislike it may imagine; witness Kronecker.

A yet simpler illustration from the same source is this: "If I can not admit that 'there are infinitely many primes' has no meaning, it is simply because it seems evident to me what the meaning is." Less than thirty years ago few rational human beings would have doubted that the assertion about primes has a clear, simple meaning. To-day, it is classed by some with apparently meaningless noises, like "2 implies that 2 implies 2," which is an example of what some call "ideal theorems."

When I remarked earlier that the philosophical implications of the theory of algebraic numbers had escaped gen-

eral notice (perhaps fortunately) I had ideal theorems in mind. Any one reading Hilbert's paper of 1925 (*Mathematische Annalen,* vol. 95), and his earlier works on the postulational method in mathematics, will be interested in tracing the evolution, unconscious perhaps, of his thought through the great report (1894) on the theory of algebraic numbers and ideals to the epoch-making treatise on the foundations of geometry (1899), down to the present theory of proof, whose aim is to establish the consistency of mathematics as mathematicians know the subject and as scientists blindly use it.

And, while one is speculating, he may try to imagine what Hilbert's theory would have been like had the report on algebraic numbers never been written. The analogies from ideals might have been replaced by more familiar ones, such as the use of ordinary complex numbers in the proof of real identities. But, at that, one imagines, the shades of Cauchy and Kronecker, the one with his algebraic keys, the other with his more easily apprehended modular systems, would rise to object and claim a hearing for their less mystical constructions. Ideal theorems, one imagines, would have a hard time evading the test of constructibility which Kronecker imposed upon his mathematical creations. They can of course escape any such cramping prison by soaring to a higher type of mathematical truth. But if they take that way out of the world of sense they will need an ideal axiom of ideal reducibility to bring them back again, and such axioms seem to be under suspicion at present.

A strict finitist might dismiss all ideal theorems as being beyond the province of mathematics. But, in dismissing them, he would say goodbye forever to a great host of mathematicians whose works many still find interesting and profitable.

Entirely elementary difficulties like those quoted bring out more sharply than others, perhaps greater and closer to the professional activities of mathematicians during the past seventy years, the quandry in which mathematics today finds itself. For this reason I have avoided allusions to current controversies about the infinite, the theory of assemblages, the use in modern mathematics of Aristotle's law of the excluded middle and the method of indirect proof, and existence theorems, all of which are being attacked with varying degrees of ferocity by those who call themselves finitists and intuitionists.

I have tried merely to suggest to mathematical laymen that the present state and past experience of mathematics would seem to counsel extreme caution in accepting any speculation begotten by science on too willing mothers outside its traditional province.

The incredible but true and rather humiliating aspect of the present disputes over the validity of mathematical reasoning is not that we are offered a choice between cold skepticism and emotional belief, but that such a choice respecting sober propositions of everyday classical mathematics, such as the scientist uses constantly and without question in his work, is not itself flagrant nonsense. The sane, middle road which some would wish to travel has not yet been proven to exist, and those who try to take it in the prevailing darkness may find themselves falling down an abyss.

10. After all this, is there any good reason why mathematicians should feel discouraged? I believe not, and I shall try to justify my belief by two howlers which I came across recently. There are many more like these if any curiosity seeker cares to hunt for them. Here is the first, and it beats anything that any pessimist can possibly imagine.

"The golden age of mathematical literature is undoubtedly past."

This is significant only when it is dated. The year is 1813, and the prophet was the English mathematician Charles Babbage, of calculating engine fame, writing in the preface to the "Memoirs of the Analytical Society."[5]

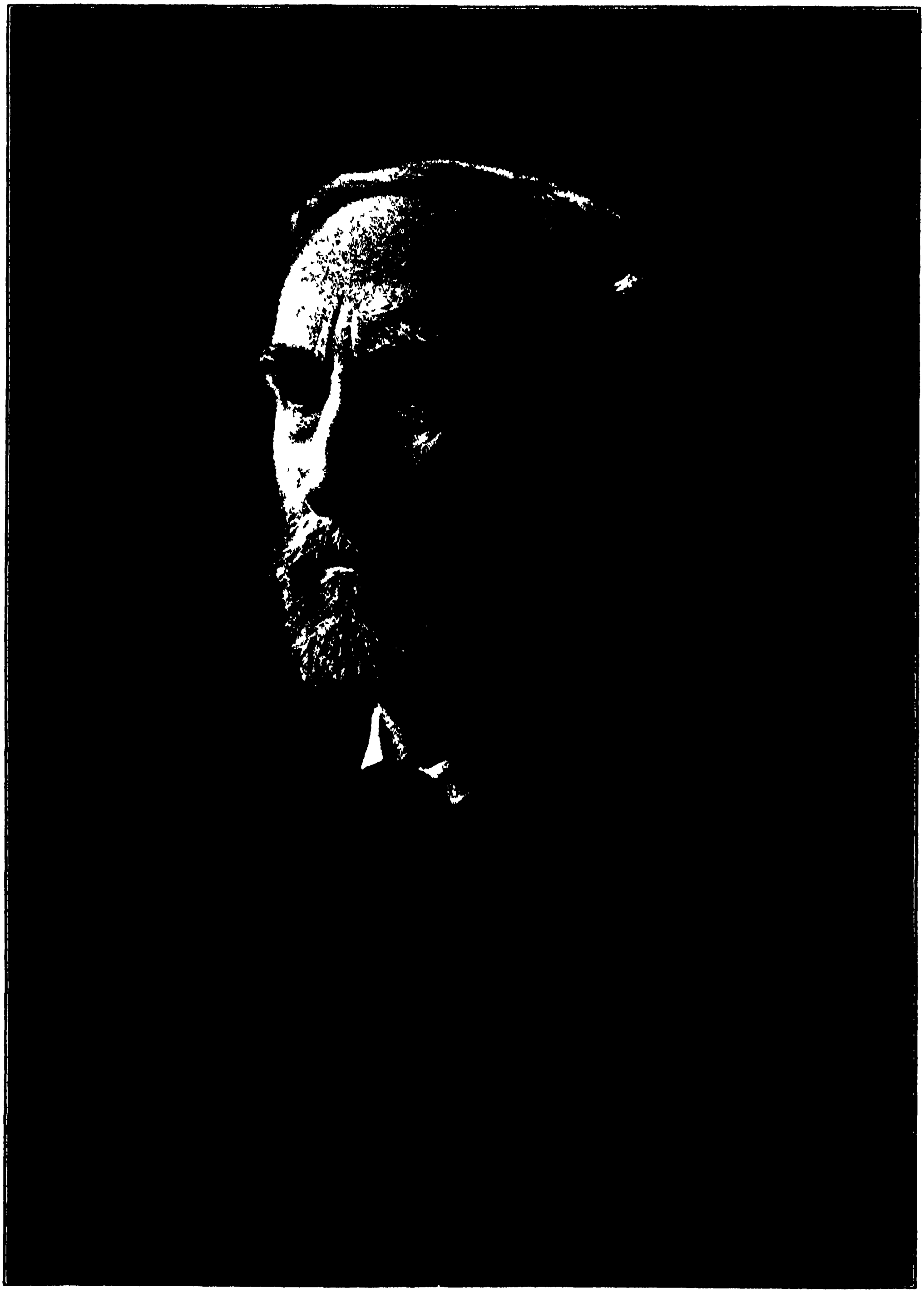
In 1813, Riemann was −13 years of age, Hermite −9, Cayley −8, Kummer −3, Sylvester 1, Galois 2, Weierstrass 2, Jacobi 9, Abel 11, Lobachevsky 20, while Cauchy was living on borrowed time at the ripe age of 24, and the venerable Gauss was still lingering on in his dotage at the extreme old age of 36. These dismal perspectives might be continued far, but for the repose of Mr Babbage's soul we forbear

When Babbage wrote, there was but little in the luxuriant literature of mathematical analysis that a student of Abel, Cauchy and Weierstrass would recognize as proof. By the time the intuitionists, finitists, formalists and others have settled their differences or agreed to differ *ad infinitum*, there may be as little left (according to the pessimists) in the rigor of Abel, Cauchy and Weierstrass for our successors to admire as that great triumvirate left intact from their predecessors for us to believe. But hear Mr. Babbage on this point, again speaking in 1813.

> The foundations of a vast edifice (mathematics) have been laid; some of its apartments have been finished; others yet remain incomplete, but the strength and solidity of the basis will justify the expectation of large additions to the superstructure

As Babbage can not be held responsible for not having heard of Kronecker, Brouwer, Weyl and Hilbert, we may overlook his unfortunate slip about the basis, and, on the intuitionist principle that two wrongs are as likely as not to cancel and leave one right, predict that 1930 in retrospect will appear as a worse year for prophecy than even 1813

[5] The preface and the memoirs are unsigned For the information that the preface is due to Babbage, I am indebted to Professor R. C. Archibald A copy in the Brown University Library has the names of the authors written in.



J. Willard Gibbs

REMINISCENCES OF GIBBS BY A STUDENT AND COLLEAGUE

By Professor EDWIN BIDWELL WILSON

SCHOOL OF PUBLIC HEALTH, HARVARD UNIVERSITY

WHEN last spring I was asked to agree to give the Gibbs' Lecture on this occasion, I assented on the assumption that before the time came for the lecture to be delivered I should have been entirely relieved of my executive responsibilities to the Social Science Research Council and should have had opportunity to prepare from a considerable dossier of investigations in progress a scientific paper somewhat fit to take its place with the previous lectures given in this series[1] As it has turned out, I have not had in full the expected relief and must appear before you with a very general talk of a personal and reminiscent nature. I will not apologize; it may well be that you prefer that type of address from me, and in view of its type I must be expected to speak without apology a good deal in the first person After all, one's personal recollections are his own; they may have little of truth in them, for memory is not infallible; to use a detached third-person style of composition may give them in appearance a greater substance of objective fact than they really merit.

To give you some appreciation of the very inadequate background with which I at the early age of twenty came into contact with J Willard Gibbs may I state that my undergraduate work was at Harvard and in mathematics, which meant pure mathematics. In the spring of 1899 Professor W. F. Osgood, with whom I had taken a number of courses and who was good enough to take a real and much appreciated interest in me, suggested that I go to Yale for my graduate work. Some of you who have a knowledge of the relative standing in pure mathematics of the departments at Harvard and Yale at that time may think the advice extraordinary. It was, but it was extraordinarily good. As Professor Osgood pointed out, I had been long enough at Harvard and had specialized sufficiently in mathematics to get the greater part of the best Harvard had to offer in point of view, and a change would be beneficial to me[2] He spoke of Pierpont and of Percy Smith whose interests were somewhat different from his own and those of Professor Bôcher with whom I had had more work than with any other than Osgood. It is my impression that neither Osgood nor Bôcher mentioned Gibbs to me. But when B O. Peirce heard that I had decided to go to Yale he remarked that down there I might come across Gibbs "whom some of us here think a rather able fellow." Had

[1] M. I. Pupin, "Coordination," 1923; Robert Henderson, "Life Insurance as a Social Service and as a Mathematical Problem," 1924 Bull Amer. Math. Soc, 31, 227–252, 1925, James Pierpont, "Some Modern Views of Space," 1925; *Ibid*, 32, 225–258, 1926; H. B Williams, "Mathematics and the Biological Sciences," 1926; *Ibid*, 33, 273–293, 1927; E W. Brown, "Resonance in the Solar System," 1927; *Ibid*, 34, 265–289, 1928; G. A. Hardy, "An Introduction to the Theory of Numbers," 1928; *Ibid*, 35, 778–818, 1929; Irving Fisher, "An Application of Mathematics to the Social Sciences," 1929; *Ibid*, 36, 225–243, 1930.

[2] This sort of generosity is not unusual at Harvard; taken with reasonably good provision for traveling fellowships, it has deprived the Harvard Graduate School of a goodly number of students of the best grade, much to the advantage of the students and of science, and thus indirectly to the advantage of the university.

SAMUEL WILLARD

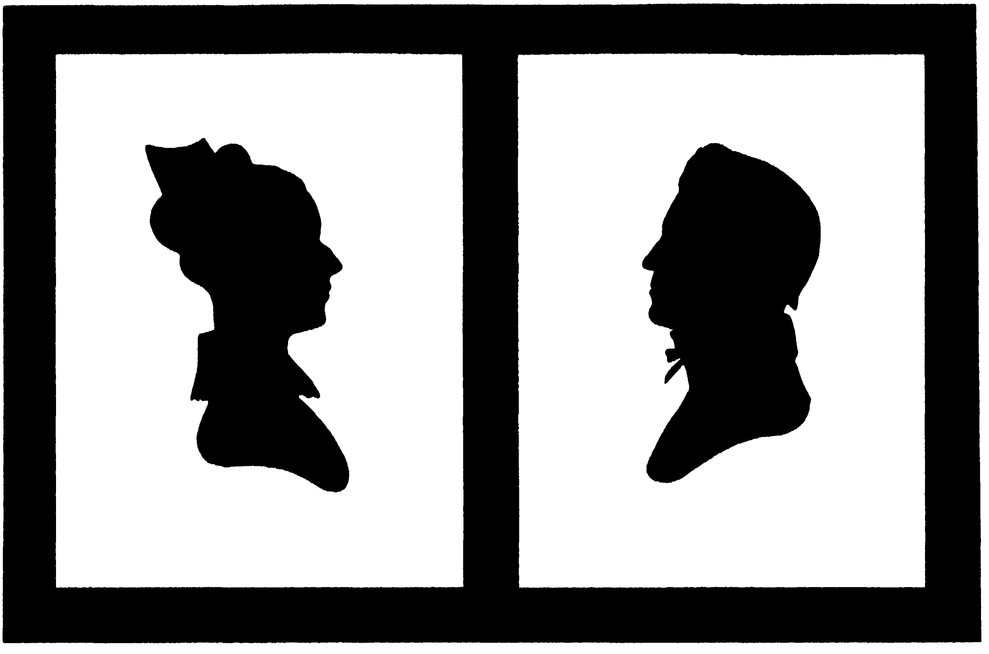
PASTOR OF OLD SOUTH CHURCH, BOSTON. GREAT, GREAT, GREAT GRANDFATHER OF GIBBS AND VICE-PRESIDENT OF HARVARD COLLEGE. (HE WAS PRESIDENT IN FACT BUT VICE-PRESIDENT IN NAME BECAUSE HE REFUSED TO LIVE IN CAMBRIDGE AS WAS REQUIRED BOTH THEN AND NOW OF THE PRESIDENT.)

I known Peirce then as well as I came to know him later I should have taken this remark as indicating a person of the highest quality under whom I must surely plan to study, but at the time I disregarded it entirely. I went to Yale to study with Pierpont and Smith.

How came it that I studied with Gibbs? That was one of life's minor tragedies When I got to Yale in the autumn of 1899 and was laying out my year's work with A W. Phillips, dean of the graduate school, it appeared that there were only three courses I considered worth while, whereas four were needed for full-time work Phillips suggested that I add Gibbs' vector analysis I protested that according to its description it was not materially different from quaternions, of which I had had a full year under J. M. Peirce, and should hardly count as a course for me The logic was unanswerable, but the circumstances overbore it; I had to have four courses and the dean would count vector analysis even though it was a sort of review; so I registered for it with a sneaking suspicion that my good master Osgood had made a mistake in sending me from a mathematically first-rate institution to a second-rate one It was one of life's minor tragedies, but too late to be helped

You are doubtless impatient that I should get along to talking about Gibbs and anxious for me to quit telling of myself; but I am just as anxious that you should realize what sort of person I was when I reached Yale after being graduated at the age of barely twenty at the head of my class with highest final honors in mathematics I was certainly immature. I was not wise enough to be confident that a new place, new contacts, new points of view have sure advantages which overbear many a technical disadvantage I was not wise enough to know that to take a subject twice from different angles and thus better master the whole might be far better in the building of a scientific life than to be forever going on to some new subject, leaving everything both new and old with insufficient consolidation It is not reasonable for you to suppose that, during the brief period from September, 1899, when I first saw Gibbs, to June, 1902, when I took leave of him to go study in Paris, never to see him again, I should have matured very greatly If I could so have failed in seeing the significance of the remark of B O. Peirce cited above, it is certain that I must have let slip many things of importance and misinterpreted or falsely remembered many others which occurred during the period of three academic years in which I came in contact with Gibbs You and I alike are on very insecure ground in believing anything I may recount here to-day.

The course on vector analysis was small, none of Gibbs' courses had more than a mere handful of students, four or six or possibly eight The course was difficult for everybody in it but me, and was easy for me only because I had previously had quaternions (which incidentally I had found difficult and perplexing, though I was amply prepared) The lectures followed the pamphlet which the author had printed privately in 1881–84 but had never published. There were no exercises assigned to the students to work—a truly continental type of course but embarrassing to Americans who are used even in graduate work to having the path made easy for them The next year, thirty years ago this month, Professor Morris, editor of the Yale Bicentennial Series, asked me to prepare for that series a text on vector analysis and told me that Gibbs had given his consent and that I should talk the matter over with him The conference was short. Gibbs remarked that he had prepared his pamphlet for the convenience of his students and for



SILHOUETTES OF THE MOTHER AND FATHER OF GIBBS

THE FATHER WAS PROFESSOR OF SACRED LITERATURE IN THE YALE DIVINITY SCHOOL, 1824–1861, AND SHOWED MANY OF THE INTELLECTUAL QUALITIES OF THE SON.

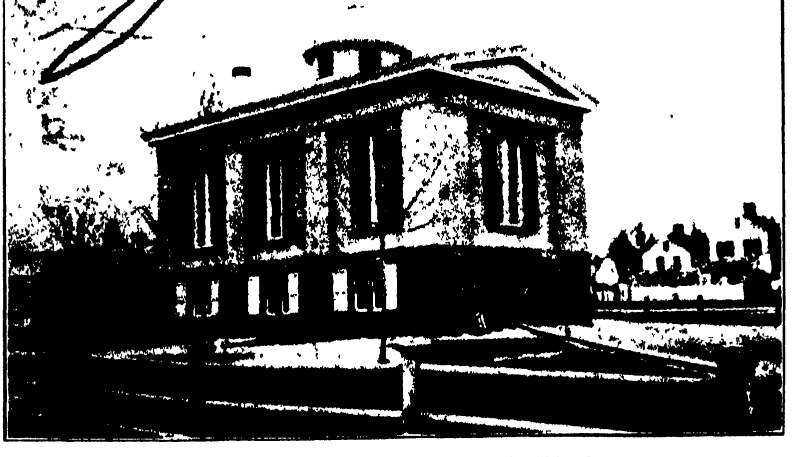
distribution privately. He said that he was busy preparing a volume for the same Bicentennial Series (his "Statistical Mechanics") and would not have time to advise on the composition of the "Vector Analysis," to read the manuscript or the proof, that I must be entirely responsible for the whole work, that I was free to write whatever kind of book I pleased, to incorporate so much of his course or pamphlet as I wished and to add whatever I desired from other sources. Somewhat seriously impressed with the magnitude and lonesomeness of the task I said I would do my best, to which he kindly replied that he had confidence that I would do very well, and after the book had appeared he was good enough to remark that it was satisfactory. That is about all the contact I had with him on the "Vector Analysis."

One topic which he treated at some length, but which I chose to leave out of the book, was crystallography; another was the theory of orbits. The latter is adequately represented in his collected works, but the former is nowhere a matter of record and I am sorry that I omitted it, particularly as all my notes on all Gibbs' courses were lost overboard by careless handling on the part of the crew of the steamship on which I returned from Paris in 1903, so that I had thereafter no way of reconstituting from my notes special material from his courses not found in print. One of the ablest students Gibbs had had in the 'nineties was G. P. Starkweather, a person as systematic as he was able. He has written out with great care his notes on Gibbs' lectures. After his early death these notes were deposited in the Yale Library. It was chiefly from a volume of these that I was able to put together that part of Gibbs' course on multiple algebra which I found it desirable to print in

the *Transactions* of the Connecticut Academy in 1907 as a precursor to some uses I wished to make of the method in developing some geometrical theorems I think it safe to say that the treatment of crystallography, though neat and interesting, was not of any great importance except as illustrating how the methods of vector analysis could be made to convert the goniometric measures taken on crystals into the desired constants of the crystal

At one time when Pierpont was lecturing on elliptic functions with some reference to the motion of the top, Gibbs happened to be developing by vectorial methods and discussing the physical meaning of the equations of motion of the top He turned to the class and with the pleasant smile which often lighted his countenance remarked that there were those who thought the top chiefly interesting as affording an exercise in the use of elliptic functions, but that he found the top a very interesting physical object on its own account No criticism of another was implied in the remark, merely an emphasis on his own point of view which he was developing to his class Although Gibbs had purely mathematical interests as in his vice-presidential address on multiple algebra to the American Association for the Advancement of Science in 1886, and in his course on the same subject, his real abiding interests were in real physical things and he rarely if ever developed his mathematical theories of physics further than was necessary to get at the important physical significance of the phenomena he was discussing; his mathematical methods were the simplest which he could devise and often extended little beyond close logical analysis. That was one reason his courses were hard; technical dexterity is easier than thinking. Read the great thermodynamic memoir if you desire verification of these statements

Except in the classroom I saw very little of Gibbs He had a way, toward the end of the afternoon, of taking a stroll about the streets between his study in the old Sloane Laboratory and his home a little exercise between work and dinner and one might occasionally come across him at that time Then there were the meetings of the mathematical and the physical clubs on occasional evenings with papers read by the staff or students I do not remember that he ever read a paper on such



THE HOPKINS GRAMMAR SCHOOL
AS IT WAS WHEN GIBBS WAS A PUPIL, 1849-1854

GIBBS AS A YOUNG MAN, FROM A DAGUERREOTYPE

occasions, but he was usually in attendance and apparently paying close attention; sometimes he would make very brief remarks after the speaker concluded and the penetration of those comments was noteworthy On one such occasion when we had been hearing of the then quite new electron theory of the constitution of the atom Gibbs said that it must be getting nearly time for him to move on, that for many years he had been troubled over the problem of reconciling the number of degrees of freedom in the molecules with the value of the ratio of the specific heats at constant pressure and constant volume and that if we were to introduce all the new degrees of freedom implied by the electron constitution he would be still more at a loss. This was, of course, before the introduction of the quantum conditions

He could be seen at faculty meetings, quiet and attentive I do not recall hearing him speak but once, and then with few words much to the point Once I ran across him in the library surrounded by books on the theory of numbers and reading a thesis on algebraic numbers just presented for the doctorate. I remarked that I had not realized that he was familiar with the

ANOTHER DAGUERREOTYPE

theory of algebraic numbers He replied that he was not, but that with the aid of some books he thought he might be able to come to a decision as to whether the thesis was worthy of acceptance Once I desired to consult some books which were not in the library but which I had seen on the shelves in his office during a lecture. I ventured to ask whether I might borrow them. He was entirely willing As I picked the books off the shelves I noticed that the pages had not been cut and inquired whether I might cut them, to which he replied: "Certainly, if you think it worth while" Probably I looked abashed, for he added. "The author kindly sends me all he writes; there is a great deal of it; I sometimes feel that a person who writes so much must spread his message rather thin"

There may be some interest in a letter written by Gibbs to me just a month before he died:

New Haven Mch 28/03

Dear Mr Wilson

I think that you will have next year

2 hrs Non Euclidean Geometry

2 hrs Mechanics

2 hrs Introduction to Math.Phys.

6 hrs Freshman,

or something very like that We will know better a little later.

HOPKINS GRAMMAR SCHOOL

AS IT WAS AT THE TIME GIBBS WAS A TRUSTEE, 1881–1903. GIBBS' INTEREST IN THE SCHOOL WAS ONE OF HIS VERY FEW INTERESTS OUTSIDE HIS WORK AND THE FAMILY CIRCLE. HE SERVED AS SECRETARY AND TREASURER OF THE BOARD FOR THE GREATER PART OF HIS PERIOD AS TRUSTEE AND SOMETIMES CONFERRED THE DIPLOMAS OF THE GRADUATING EXERCISES.

I think that the reasons wh you expressed so eloquently & I may add so discreetly to Dr. B—, would apply to an abridgement. We can not take for granted that an abridgement wd not interfere with the sale of the larger book. The larger book is pretty heavily handicapped by its price, as it is & in competition with a cheaper edition could hardly hold its own. Moreover, anything requires time to be well done, & I think to write a short book takes as much time as a longer one.

I did not mean to say that Hamilton did not have the equation

$$q^2 - 2Sq \cdot q + (Tq)^2 = 0$$

He doubtless would recognize the equation as correct, & may have written it in just that form. Only I do not see how he could have recognized that it is (I don't care whether you say, identical with or) analogous to the Ham-Cayley equation, because I suppose that he never was aware that a quaternion might be regarded as a matrix. I suppose that that was a discovery of the elder Peirce, as stated by Cayley in the chapter wh he wrote in Tait's "Quaternions."

I am glad that you find that instruction in America compares not too unfavorably with that in France. However, what you want to do is to get the best you can out of France, wh certainly will be a great addition to anything wh you may get here. I am a little surprised that you find the French Lecturers *going to pieces*. I had supposed that that was just what they never did that they always gave their lectures in good form.

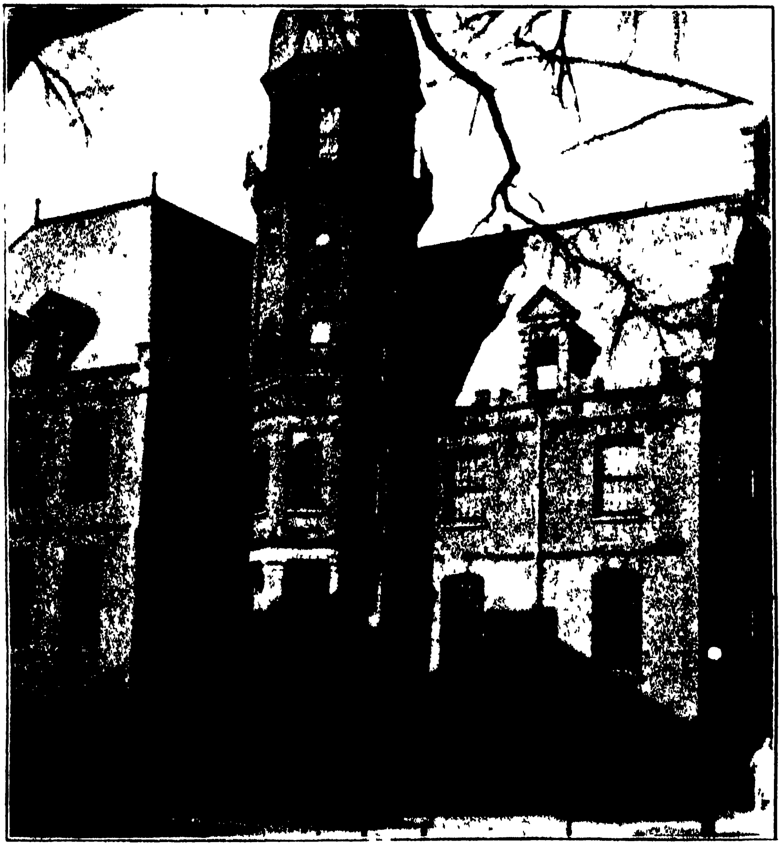
Yours truly

J. WILLARD GIBBS

Let me interrupt these personal reminiscences to give you a bit of history as it appears in the record. Gibbs was born on February 11, 1839. He prepared for college at the Hopkins Grammar School. He was graduated from Yale in the class of 1858 at the age of nineteen. In college his interests appear to have been Latin and mathematics, as he took prizes in each in more than one year of his course. He took the Bristed Scholarship of $95 for the best examination in Greek, Latin and mathematics. He won the Latin Oration in both junior and senior years. He was awarded the Clark Scholarship of $120 for the best examination in the studies of the college course which was conferred subject to the condition that the recipient continue as a graduate for one or two years pursuing non-professional studies. He did so continue and, in 1863, got his Ph.D. degree with a thesis: "On the Form of the Teeth of Wheels in Spur Gearing." In the Yale catalogues, of 1863-64 and 1864–65, he is listed as "Tutor in Latin"; in that of 1865-66 he appears as "Tutor in Natural Philosophy." Afterwards he went abroad to study. In the catalogue

of 1871–72 he reappears as "Professor of Mathematical Physics" and so continues until his death.

Except for his periods as tutor he taught only graduate work, although particularly competent undergraduates might be admitted to his courses, especially the vector analysis. It may interest you to follow the subjects he taught. From 1872 to 1881 the topics announced were capillarity, wave theory of light and sound, least squares, and potential theory with applications to electricity and magnetism. It is not to be presumed that he taught all these subjects in any one year, but the catalogues fail to state just which he did teach. It was in this period that the great papers on thermodynamics were published, but there is no reference to his teaching the subject. In 1881–82 he added to his list a course on vector analysis, having apparently not given least squares for some years. The list continues with minor modifications through the catalogue of 1885–86. For the year 1886–87 we find the first pretentious catalogue, much larger than the preceding ones, with better descriptions of the offerings. The list for Gibbs is (1) vector analysis, (2) potential theory, (3) mathematical theory of electricity and magnetism, (4) electromagnetic theory of light, (5) the *a priori* deduction of thermodynamic principles from the theory of probabilities, and it so continues through the



THE OLD SLOANE PHYSICS LABORATORY

GIBBS' OFFICE WAS ON THE SECOND FLOOR AT THE RIGHT. THE LARGE LECTURE HALL BELOW WAS WHERE HE GAVE HIS LECTURES, EXCEPT WHEN HE GAVE THEM IN HIS OFFICE

THE HOUSE AT 121 HIGH STREET BUILT BY GIBBS' FATHER
WHERE GIBBS LIVED WITH HIS SISTER AND HER HUSBAND, ADDISON VAN NAME, LIBRARIAN AT YALE. GIBBS' ROOM WAS AT THE BACK OF THE HOUSE.

year 1891-92, except for the addition of a course on the computation of orbits.

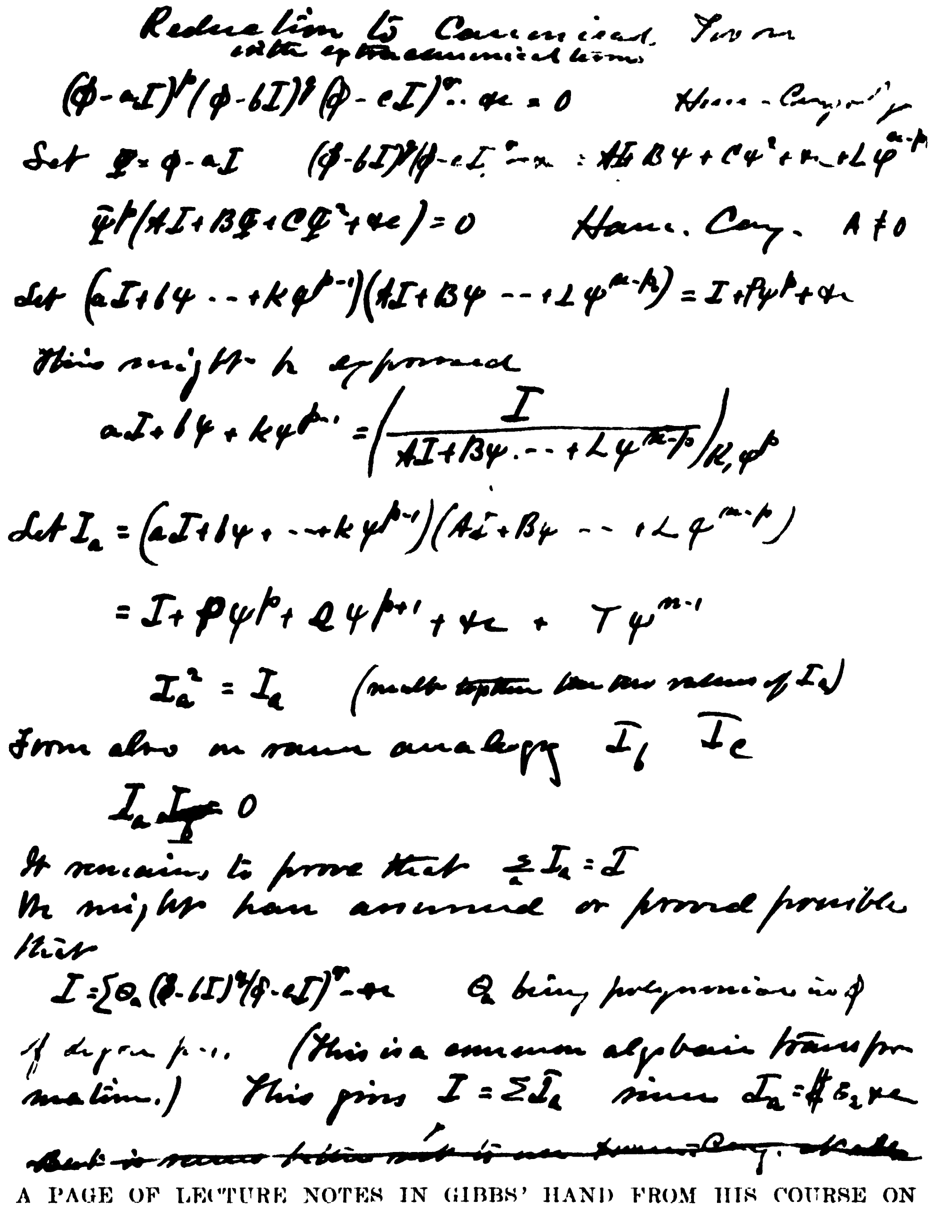
It is of more than passing interest that the classical thermodynamics represented by his own contributions has not appeared for the fifteen years since his paper was printed and that the first course announced by him in this field is apparently really his "Statistical Mechanics" on which nothing was printed until 1901 In the years 1892-94 he apparently offered a combination of classical thermodynamics with statistical mechanics and only from 1894–95 on came to divide the work into a course on his great memoir with a supplementary one on statistical mechanics. In the meantime he had added an option in advanced vector analysis and another in multiple algebra. Thus after the middle 'nineties he may be considered to have run the cycle: (1) vector analysis, (2) advanced vector analysis, (3) multiple algebra, (4) thermodynamics and properties of matter, (5) statistical mechanics, (6) electromagnetic theory of light, (7) potential theory and theory of electricity Of these (1), (4), and (6) were generally two hours per week throughout the year, while the others were one hour per week He seems to have taught about six hours per week, giving (1) yearly with (4) or (6) in alternate years, and adding on occasion one or two of the other four one-hour courses. During the three years, 1899-1902, I was fortunate enough to take all these subjects, except that the statistical mechanics (5) was not given separately, but was represented as some ten lectures

at the conclusion of his thermodynamics (4).

Except for the vector analysis I, in common with all Gibbs' students of my time, was ill prepared for his work. It was not infrequently the case that a student repeated the work to become more familiar with it, and it certainly was my intention to repeat most of the courses after my return from Paris The instruction was not poor, but the concentration of thinking of the instructor was great. Once in a while Gibbs would get lost in a demonstration He lectured without notes and what specific preparation he generally made I do not know. It was almost always some very simple affair on which he would go astray rather than something recondite The year I took thermodynamics he could not make his Carnot engine run right There was a tradition, perhaps unwarranted, that the Carnot engine was apt to trouble him Sometimes he would unravel his difficulty before the end of the hour and it was then an especial treat to see his mind work; sometimes the end of the hour would come sooner and he would have to leave the matter over until the next time when he would appear with a sheet of paper containing the demonstration.

I do not believe that Gibbs kept much in the way of notes. I imagine that he wrote the closely reasoned and highly mathematical "Statistical Mechanics" out of his head (rather than from notes accumulated during previous years) between the time in the autumn of 1900 when he agreed to produce the book and the time in the summer of 1901 when he delivered the manuscript. The reason for this belief lies in the fewness and in the character of the papers he left when he died there was practically no *Nachlass.* And yet he was known to be working on a program of publication. I know this because of the conversation I had with him in June, 1902, when I was leaving for Paris for a year's study It was by far the longest conversation I ever had with him, and of course the last. He said that he did not wish to determine my line of future interest but that he hoped I would consider taking some work in applied mathematics in Paris in addition to any I might take in pure mathematics. He ventured the opinion that one good use to which anybody might put a superior training in pure mathematics was to the study of the problems set us by nature. He remarked that in the thirty years of his professorship of mathematical physics he had had but a half-dozen students adequately prepared to follow his lectures He did me the honor to include me in the list, though I myself never felt that my preparation in physics had been adequate I asked why he had given exclusively such advanced courses, why he had not offered some more elementary work to prepare his students He replied that he had not felt called upon to do so but that if I were willing he would be glad to have me look forward to giving upon my return a general introductory course on mathematical physics, and at any rate he would be happy if I would bear the possibility in mind while abroad. He then went on to say that if I should choose to occupy myself somewhat seriously with mathematical physics he had a considerable number of problems on which he thought I could make progress and that he would be glad to talk about them on my return How much I have regretted that he did not talk of them at the time, but he gave no inkling of them

Finally he proceeded to say something of his own plans for the future. He remarked that if he could depend on living to be as old as Methuselah he would continue to study for several hundred years yet, but that as he could not except any such span of years he had decided to set about preparing some matters for publication. There were



Reduction to Canonical Form
with eigen canonical terms

$(\phi - aI)^p(\phi - bI)^q(\phi - cI)^r \cdots \text{etc} = 0$ Ham.-Cayley

Set $\Phi = \phi - aI$ $(\phi - bI)^q(\phi - cI)^r \cdots = A + B\psi + C\psi^2 + \text{etc} + L\psi^{n-p}$

$\Psi^p(AI + B\Phi + C\Phi^2 + \text{etc}) = 0$ Ham. Cay. $A \neq 0$

Set $(aI + b\psi \cdots + k\psi^{p-1})(AI + B\psi \cdots + L\psi^{n-p}) = I + P\psi^p + \text{etc}$

This might be expressed

$aI + b\psi + k\psi^{p-1} = \left(\frac{I}{AI + B\psi \cdots + L\psi^{n-p}}\right)_{R,\psi^p}$

Set $I_a = (aI + b\psi + \cdots + k\psi^{p-1})(AI + B\psi \cdots + L\psi^{n-p})$

$= I + P\psi^p + Q\psi^{p+1} + \text{etc} + T\psi^{n-1}$

$I_a^2 = I_a$ (multiply together two values of I_a)

Form also in same analogy I_b I_c

$I_a I_b = 0$

It remains to prove that $\sum_a I_a = I$

We might have assumed or proved possible that

$I = \sum Q_a(\phi - bI)^q(\phi - cI)^r \cdots \text{etc}$ Q_a being polynomial in ϕ of degree $p-1$. (This is a common algebraic transformation.) This gives $I = \sum I_a$ since $I_a = \ldots$

A PAGE OF LECTURE NOTES IN GIBBS' HAND FROM HIS COURSE ON MULTIPLE ALGEBRA

three lines of activity he desired to pursue: (1) The revision and extension of his work on thermodynamics, to which he said he had some additions to make covering more recently discovered experimental facts not yet adequately incorporated into the theory and other additions of theory apparently not yet exemplified in experiment. (2) A contribution to multiple algebra on which he said he had some ideas he thought worth while even though the subject appeared at the time not to be of much interest to mathematicians, most of whom were devoting their attention to analysis. (3) A revision of

N H Sept 26 1902

Dear Lord Kelvin.

Your problem of the '<u>caged atom</u>' in the paper wh you kindly sent me some time ago, (& wh I have since seen in the Phil. Mag. & Proc. Roy. Instit: [Vol XVII p 394?]) has given me a good deal of trouble. I cannot get the same results wh you.)

It seems to me that if the probability that the velocity of an uncaged atom taken at random lies between v & $v+dv$ is represented by

$$Ae^{-v^2}dv,$$

the probability that the velocity of a ~~taken at random~~ <u>when entering the cage</u> lies between the same limits will be represented by

$$Bve^{-v^2}dv,$$

where A + B are constants determined by the necessary relations

$$A\int_0^\infty e^{-v^2}dv = 1, \qquad B\int_0^\infty ve^{-v^2}dv = 1.$$

FIRST DRAFT OF A LETTER TO LORD KELVIN

DATED SEPTEMBER 26, 1902, PROBABLY FROM INTERVALE, NEW HAMPSHIRE. THIS SEEMS TO DEAL WITH A PAPER WHICH WAS QUITE A SHOCK TO GIBBS AS I KNOW FROM A LETTER HE WROTE ME TO CAMBRIDGE ASKING IF I WOULD LOOK THE MATTER UP IN HARVARD LIBRARY AND REPORT TO HIM. I LOOKED IT UP, BUT MY REPORT WAS SURELY USELESS; THE SUBJECT WAS DIFFICULT AND HE WAS LEANING ON A QUITE TOO SLENDER REED.

his method of computing orbits which should certainly be revised now that it had recently been printed verbatim by Buchholz in the third edition of Klinkerfues' "Astronomy" when certain important improvements were only too obvious. He asked what I should think he had best first undertake, but without waiting for reply answered that the astronomers were conservative and unlikely to be appreciative of improvements in his methods for orbits, that the mathematicians were not impatient to learn of his ideas in multiple algebra and that on

the whole he felt it was more important to set about the work in thermodynamics to which he had made no published contribution of significance for about twenty-five years.

Ten months later, in April, 1903, Gibbs died. There were found among his papers some chapter headings and the first beginnings of text on the revision and extension of his thermodynamic work. It was clear that what he intended to accomplish he carried in his head and not on paper. We shall never know what he had in mind in any of the three lines of activity. He waited and studied too long. This situation is primarily that on which I base my opinion that he wrote the "Statistical Mechanics" out of his head in something like nine months in addition to his regular teaching. The task was serious All through the winter and spring of 1900–01 he worked not only by day—the light in his study in Sloane could be seen burning at night. The manuscript was finished in the summer at Intervale, New Hampshire. After Gibbs died, A. W Phillips told me that it was this severe work that killed him. He said that they had gone together to the express office to dispatch the copy to Scribner's, that up to that time Gibbs had been quite himself, but that from the time they turned away from the office he slumped, the elasticity was gone from his gait, he was a worn-out old man, and never fully came back.

This is a thrilling story, but sad. However, it may not be true. I communicated it to my old friend Ralph Van Name, nephew of Willard Gibbs, who writes: "This may be true, but it was not apparent to his family," and later:

. . . my comment on the incident of the delivery of the manuscript of the "Statistical Mechanics" was not made in a spirit of criticism, but merely as a statement of my recollection, and of that of my sister, whom I had consulted about it. Though both of us were in Europe at the time of Willard Gibbs' death, I did not leave New Haven until June, 1902, and she not until March, 1903. It is unquestionably true that my uncle worked to the lim t of his strength in trying to get the volume finished on time, and that he did not get over the effects for a good while But both of us have the impression that he seemed to be in practically normal health and spirits by the Autumn of 1901. . . . My uncle's final illness was a sudden and acute attack of a nature which has no obvious connection with his overwork two years before—it was an intestinal obstruction which the doctors were unable to relieve.

I may say that all through the academic year 1901 2 Gibbs seemed to me to be in normal condition, and in his conversation of June, 1902, of which I have given so long an account seemed to be looking cheerfully and healthily ahead with real pleasure in the prospect which he was outlining and with no discernible feeling that it might not be finished—indeed he spoke as one surely counting on being active on my return fifteen months later.

If I have gone at such length into this story I have done so chiefly because it so well illustrates stories which come with the best intention of truth from persons near to Gibbs, with just as high desires to tell the truth and nothing but the truth as I have on this occasion, but which none the less can not be wholly credited, quite as I do not wholly credit as fact my own statements. There is the story that at home, where he lived all his life with his sister, who had married his friend and classmate, Addison Van Name, he always insisted on mixing the salad, on the ground that he was a better authority than the others on the equilibrium of heterogeneous substances A very pretty conceit, and one vouched for by a colleague much closer to Gibbs than I, but I daresay both the fact and the statement of reason for the fact would not be substantiated by the family. Another story refers to his letter to *Nature* in comment on and disproof of Lord Kelvin's proposed experi-

ment to determine the velocity of longitudinal waves in the ether. It is said that when a colleague told him that he had just seen the letter in print Gibbs blushed and said that he could not believe the editor of *Nature* would print it. That illustrates his modest and retiring disposition, which was a conspicuous trait, but seems hardly credible.

One often hears lament at Yale and elsewhere that Gibbs' colleagues did not capitalize his great discoveries in physical chemistry by developing the subject experimentally and intensively in New Haven from 1876 on. The comment often takes the turn of wondering how much greater rôle American science would have played in the growth of physical chemistry if Gibbs had accepted the offer to go to the Johns Hopkins University instead of remaining at Yale. How much difference would it have made? Perhaps very little. What efforts Gibbs made to develop physical chemistry at Yale I do not know; perhaps none. That he knew his thermodynamic work was important and knew so when he printed it I have no doubt; but I have noted above that he appeared not to have lectured upon it in his cycle of courses for about fifteen years after its completion, preferring for some reason to teach other subjects,—and the subject-matter of the memoir is not such as would be likely to diffuse around any university without exposition by the master unless by chance there were at hand some almost equally competent person who very much needed the work as a basis for his own, and knew that he needed it. Gibbs was not an advertiser for personal renown nor a propagandist for science; he was a scholar, scion of an old scholarly family, living before the days when research had been *re'*search. Probably he had faith that when the time was ripe for his thermodynamics, the doctrine would spread.

Another beautiful legend is that Gibbs was not appreciated in this country or at Yale during his life. It is probably true that his name was not well known in the ordinary Yale alumnus before the recent time when his photograph and some eulogy of him were widely circulated to the alumni during a drive for funds. But the efforts which were made to arrange for printing his long and costly paper in the *Transactions* of the Connecticut Academy in 1876–78 were a high testimonial to the faith of his local contemporaries in his work. He was elected to the National Academy at forty, the average age of election being fifty, and only the year after the appearance of the second half of the thermodynamic memoir. In 1881 he received the Rumford Medal from the American Academy of Arts and Sciences, which means that a group of his contemporaries in Boston appreciated promptly and highly his contributions in the field of heat. Of course he did not have the notice which Einstein receives to-day; he had no press agents and surely wanted none. There seems to be every evidence that he received the type of recognition to be expected.

Whether the establishment of the Gibbs Lectureship by the American Mathematical Society should be ranked as one of the honors to his memory or whether it belongs with the circularizing of his photograph to Yale alumni as an attempt to get something through exploiting his name I will not venture an opinion. It is well known that this society through all of its life has been chiefly in control of those interested chiefly in research in pure mathematics. It is also well known that the group of American students who went to Germany to study mathematics in the late 'eighties and early 'nineties, at the very time when Klein was emphasizing the need in Germany of a greater attention to applied mathematics, came back to this country with a determination to promote only pure mathematics. This may have been

wise at the time. American mathematicians had been too exclusively interested in the applications. We needed emphasis, perhaps temporarily over-emphasis on pure theory and rigorous procedures, on analysis as it had developed in Europe. The lengths to which this emphasis was carried may be illustrated by my telling a story which happened not so long ago. When E. W. Brown, a past president of this society, was at last naturalized as an American citizen and thus became eligible for election to our National Academy of Sciences, I asked one of the leaders in the section of mathematics of that academy and also a leader in this society whether the mathematicians would not nominate Brown to the academy. He replied in a breezy vernacular "Not till Hell freezes over" —Brown was to him not a mathematician, but Brown was here in good company with Gibbs, G. W. Hill, H. A. Newton, Newcomb and others. Another story shows how non-mathematicians were impressed with the point of view. I once met at the Cosmos Club an eminent expert in international relations who asked why I happened to be in Washington. I replied, "To attend the meeting of the National Academy of Sciences." "But," said he, "you are a mathematician not a scientist," and added, "oh, yes, I remember now that it is an academy of the sciences and of mathematics."

The mathematician has a dilemma, a choice. In so far as he turns his attention to the abstract theory of his subject he is not a scientist dealing with observed fact but a philosopher playing with *a priori* hypotheses. It is only when he turns his attention to applied mathematics that he becomes a scientist. With the obvious need of specialization to-day, I would not limit the choice of the individual mathematician; he should be free to follow his bent or the exigencies of the institution he serves. A great national mathematical society, however, should not limit its interests, it should cover the whole field of mathematics both pure and applied. In doing so it puts itself right on the pinnacle of intellectual effort. There is no problem requiring more brains, sounder judgment, better total adjustment internal and external, than that of uniting the logical and operational techniques of pure mathematics with the infinite variety of observable fact which Nature offers to our contemplation with a ringing challenge to our best abilities. It was in this field that Gibbs was supreme. He had studied with Weierstrass and was not unmindful of mathematical rigor; in the paper in which he pointed out that phenomenon of the convergence of Fourier Series, which has come to be known as the Gibbs phenomenon, he showed his appreciation of mathematical precision as he did on other occasions. But fundamentally he was not interested in rigor for itself, he was inspired by the greater problem of the union between reflective analytical thought and the world of fact. He did not feel that one should not study pure mathematics; he was not one-sided or dogmatic in any of his views. What he said was that *one* of the uses of a good mathematical background was in the study of the problems set us by nature. And if I had one special inference to draw from my contact with him to give you to-day it would be that the American Mathematical Society should follow for its own good his judgment on that matter. There are indeed indications that times are somewhat changing and that in the future the mathematics in which you as a society are interested will be all mathematics, pure and applied. When that time comes there will be no possibility of raising the query as to whether the Gibbs Lectureship may be only lip service to a great name, for it will be evident that the thought of this society is itself in no

small measure a constant testimonial to that great thinker, J. Willard Gibbs.

You may be somewhat disappointed that I have no very striking personal reminiscences to recount, but what should you really expect in the way of impressions gained by an immature young fellow in the early twenties of a mature quiet scholar forty years his senior. Gibbs was not a freak, he had no striking ways, he was a kindly dignified gentleman. I came to his courses in the days prior to tutorial systems when students were not expected to take the time of their teachers outside the classroom for personal contact and when teachers did not feel a moral urge to guide their students otherwise than by instruction given in course. I am not sure but this was better for both student and teacher even if it has resulted in a less picturesque address to-day than the one which some now twenty-year old at the California Institute of Technology could give thirty years hence about Millikan.

ANIMAL PARASITES OF WILD AND DOMESTIC MAMMALS AND THEIR RELATIONSHIP TO HUMAN WELFARE

By Professor ERNEST CARROLL FAUST
THE PARASITOLOGY LABORATORY, DEPARTMENT OF TROPICAL MEDICINE, TULANE UNIVERSITY

INTRODUCTION

THERE is substantial evidence favoring the belief that all living organisms have their parasites, from the lowest bacterium, with its bacteriophage, to the highest mammals, including man. These parasites are other organisms which for one reason or another have found it advantageous to lose their identity as self-sufficient independent individuals, and have become associated with a donor organism, called the host. In some instances this host-parasite association is a very temporary one, in which the parasite merely consumes the food which the host has rejected. Thus various tumble-beetles very industriously work over the dung of most mammals and from this dejecta obtain their food supply. However, in doing so, they commonly ingest the eggs or larvae of certain roundworm parasites of the mammals' intestinal tract and themselves come to serve as intermediate hosts of these roundworms. In other cases the parasite is a biting insect or a tick, which applies itself to the mammals' skin, inserts its external mouthparts and draws up a meal of blood. Among certain biting flies and their allies it is only the "deadly female" which is a blood feeder. The amount of blood consumed is very small compared with the total supply of the host, but inconvenience is frequently caused by the injury at the site of the bite. Not infrequently the "saliva" of the insect, which is injected into the wound just before the blood is sucked up, is poisonous to the host and causes local itching and at times a general reaction. Again, many biting insects inject larval parasites into the blood stream of the host. These larvae mature and give rise to serious diseases, such as the human sleeping sickness of Africa, malaria, yellow fever, dengue, filarial disease, etc. Other insects, such as lice, contaminate with their dejecta the wounds which they make, and in so doing produce typhus fever and relapsing fever.

There are, moreover, large numbers of parasites which have become so intimately associated with their hosts that the condition is an obligatory one for the parasite. Certain flies lay their eggs in wounds or ulcers; others deposit their eggs or larvae under unbroken skin; still others oviposit on food which is swallowed by various mammals. The eggs hatch in these locations, the larvae grow at the expense of the host's body, cause serious injury and frequently produce death. Many parasitic organisms are taken into the body with food or drink and become attached to the intestinal wall of the host, where they proceed to develop and reproduce. Some of these species of parasites taken into the mouth with food migrate from the digestive tract into the liver, lungs, kidneys, muscles, blood or lymph channels, and develop in these remote locations. Another group of parasites, such as the hookworms and the blood-flukes, directly invade the unbroken skin of the host, and after an involved migration through the body come to settle down in the intestinal wall or its adjacent blood supply. All these latter groups of parasites have become so intimately associated with the life of the

host that their condition is an obligatory one; in other words, life is impossible for them without this association.

These illustrations serve to show the wide range of habits of the parasite in relation to its host. It will now be possible to make inquiry into the types of parasites found in wild and domestic mammals.

Types of Animal Parasites of Mammals

The animals which are found in parasite association with mammals may be grouped into two main divisions, *ectoparasites* and *endoparasites*. The former are essentially all insects and their allies which live on the skin or in its superficial layers. The latter consist of one-celled animals or protozoa, and various types of parasitic worms, as well as certain insects and their allies. The endoparasites live in all of the deeper tissues of the body, but each parasite usually has a preference for certain tissues. In view of the fact that there are tens of thousands of species of parasites of mammals it will be possible to use only certain forms for purposes of illustration.

Ectoparasites

This physiological group includes the ticks, mites, lice, fleas, flies, mosquitoes and bugs. With the exception of the filth and flesh flies and the feather lice of birds all these forms are bloodsuckers, *i.e.,* they depend on blood as a source of food for themselves.

Ticks. The tick lives for the greater part of its life closely associated with the ground and only crawls upon and becomes attached to mammals when it is in need of food. Whether it be the larva, the seed tick or the mature tick, it buries its external mouth-parts into the skin of the mammal and proceeds to feed until it is fully engorged, its abdominal wall swelling out to accommodate the ingested blood. In this respect it is much like a leech, and when the feeding is completed it drops off and becomes dormant. Such a single feeding in the case of certain species of ticks may last for four or five years. Many of these ticks are not especially selective of their host. The writer has found both the castor-bean tick (*Ixodes ricinus*) and the fowl tick (*Argas persicus*) on the following hosts: dog, ox, wild boar, Bactrian camel, hedgehog (*Erinaceus dealbatus*), jungle-fowl (*Gallus indicus*) and the gecko. He has also had personal experience with these two species of ticks. Ordinarily the drain on the blood is minimal and no ill effects are experienced except for temporary pain at the site of puncture. However, certain ticks, such as the Rocky Mountain sheep tick, *Dermacentor andersoni,* secrete a "venom" which produces paralysis in sheep and in children. Furthermore, ticks are responsible for transmitting the following diseases to various mammals: (1) relapsing fever (man); (2) cattle fever of Texas, Africa, Russia, Japan, etc., and related fevers in sheep, horses and dogs; (3) heart-water fever of Southeast Africa (cattle); (4) Rocky Mountain spotted fever (sheep are reservoirs, man becomes seriously ill), and (5) tularaemia (sheep, rabbits, muskrats, man). Diseases such as Texas cattle fever produce jaundice, anemia, malnutrition and frequently death in the host. In cattle this disease renders the animal unsatisfactory either for beef or milk production. The Bureau of Animal Industry of the U. S. Department of Agriculture maintains a rigorous quarantine in the tick-infested areas of the Southern United States, a justifiable procedure, but one which works a great hardship on cattle breeders and shippers. Prevention of tick infection is a most difficult problem. Various "dips" have been used but these are not always effective, since some of the ticks may remain attached to skin folds, particularly where the fur is long.

It need not be pointed out that for man tick-borne relapsing fever, Rocky Mountain spotted fever and tularaemia are very serious diseases and that the mortality in these infections is high.

Mites. Mites are related to ticks but are smaller and have a less leathery skin. There are hundreds of species which trouble mammals. Some of these are incidental or accidental and need not be considered here. There are several species, however, which produce mange and are not only a great aggravation to the unfortunate host, but are particularly detrimental to the production of marketable pelts. The most common of these mange mites is *Sarcoptes scabei.* It can infest almost any mammal, and while it is most commonly found in the ear-lobes of fur-bearing animals, it also frequently involves the whole skin. Animals in the wild are much less subject to attack from these mites than are those in captivity. Zoological gardens frequently have to contend with epidemics of mange among their primates and cats, and silver fox breeders are frequently confronted with the problem. Sulphureted lanolin oil, rubbed into all affected areas of the infested animal, is the standard remedy. Sarcoptic itch in man is also a serious skin disease, very resistant to treatment. It has not been proved, however, that the human variety is identical with that of other mammals.

The little red chigger, or harvest mite, is a pest to man in the Southern United States. In Japan and Formosa and probably also in the Malay States and Sumatra, certain of these red mites carry an infection known as "river fever," which is very fatal to man. In Japan the mites are commonly found on certain field mice (*Microtus montebelli*), while in Sumatra certain birds harbor them. In Panama the conejo pintado (*Cuniculus paca virgatus*) is a favorite host of these mites.

Lice. There are two kinds of lice, biting lice and sucking lice. The former are commonly called feather lice, because they are so common amongst the feathers of birds. They are technically known as *mallophaga.* Very few species have been described from mammals. These forms feed on the barbules of feathers of birds and the epidermal scales and oily secretions of mammals. They are of little economic importance in mammals. The sucking lice (*anoplura*), on the other hand, are of immense economic importance. They are confined exclusively to mammals, particularly rats and mice, horses, oxen, pigs, monkeys and man. The human forms, the body louse, head louse and pubic louse, are indicative of the poorest sort of personal hygiene, while the body louse is responsible for the transmission of typhus, trench fever and the commoner types of relapsing fever. Scrubbing of the body with soap-kerosene mixtures in water and delousing of clothing and kennels with live steam are indicated wherever animals become infested.

Fleas. Fleas are mostly objectionable because of their irritating bites. The commonest species are those found associated with rats and mice, dogs and cats, and man. The fleas of rats, of the ground squirrel and of the tarbagan are of medical importance because they transmit plague from rodent to rodent and from rodent to man. Dog and cat fleas transmit the dog tapeworm, *Dipylidium caninum.* All these forms are on the mammalian body only during their brief blood-sucking period, after which they drop to the floor or ground and lay their eggs, which develop into larvae and then pupate, returning to feed only after the pupae have been transformed into adult fleas. Of especial importance in the realm of true parasites is the chigoe flea, a species commonly found in warm climates. These fleas, which parasitize wild and domestic mammals alike, as well as man,

feed on the hosts' blood, after which they copulate and the female burrows under the skin, particularly that of the feet, leaving a small opening through which she lays her eggs. By this time she is as large as a small pea and the surface of the skin becomes bulged up into distinct boil-like heads, which frequently become secondarily infected with bacteria. The treatment consists in removing the females with a sterile needle and cleaning out the wound with an antiseptic such as kerosene.

Flies and their allies. From the point of view of their relations to parasitism these insects may be divided into two groups, (1) the filth and flesh flies and (2) the biting flies. Even flies which are otherwise very closely related may be separated on this basis, as, for example, the ordinary house fly and the stable fly.

Filth and flesh flies are a serious menace to mammals. In the first place, they may introduce bacteria into accidentally contracted wounds and produce a bacterial infection. More serious, however, is the development of larval stages of these worms (maggots) in the mammalian body. In some instances the eggs of the fly may be swallowed as a food contamination, hatch out in the intestine and develop there, producing multiple ulcers. *Gastrophilus equi*, commonly found in horses' skin, is a good example of this type. Maggots from eggs of practically all the filth flies will hatch in the human intestine and produce more or less trouble. In other species the female fly will intentionally lay eggs in wounds (*Sarcophaga* spp.) of mammals or dart against the conjunctiva of the eye (*Chrysomyia bezziana*) and deposit eggs. In both these cases the larvae hatch out and feed on the tissues, usually becoming secondarily infected with bacteria. More serious still are the lesions produced by larvae of flies, where the females introduce the eggs or viviparous young under the skin or in the nasal sinuses. The bots (larvae of *Hypoderma bovis* and related species) are particularly destructive to the skin layers of cattle, deer, etc. The skins of such animals are worthless for use in the industries. *Oestrus ovis* in sheep, goats and related mammals invades the nasal sinuses and develops there, at times even invading the brain. In both wild and domestic mammals these flies are all serious pests. The flesh fly is the cause of great suffering in wounds of man on the battlefield. Wherever man is closely associated with mammals harboring the bot or sheep maggots and other destructive fly larvae, he, too, may become infested in a similar manner.

Under the group of biting flies and their allies there is a very large number of species with varied life histories, which have in common the custom of sucking blood. There are the common stable fly (*Muscina stabulans*), the horse flies (tabanids), *Chrysops*, the tse-tse flies (*Glossina* spp.) of Africa, and many others which belong to the larger species. Then there are the many hundreds of species of mosquitoes, the sand-flies (*Phlebotomus* spp.), the midges (*Culicoides* spp.) and the black flies or buffalo gnats (*Simulium* spp.). The females of all these smaller forms suck blood, and, while the blood of birds is equally acceptable, mammalian donors are usually more available.

In the large, the irritation produced by the bites of flies is incalculable. When it is remembered, however, that many of these flies transmit diseases which are far more serious than their bites, the economic importance of this group will be appreciated. Just to mention a few of the diseases, we may note the following: sleeping sickness of man in Africa, and the trypanosomiases in wild and domestic mammals; all the known species of filarial infection in man and mammals; yellow fever, dengue, sand-fly fever, and tularaemia. The im-

portance of these transmitters in human medicine is just beginning to be appreciated; their significance in the causation of disease in wild mammals is still unfathomed.

Bugs. Many bugs will bite mammals on provocation, but most of these bites are accidental. However, the bedbug and its allies are dependent on blood-sucking as a source of food. Likewise the assassin-bug and the "kissing-bug" belong to this latter category. The bedbug has been accused of transmitting an Oriental disease known as kala-azar, also certain spirochetal infections, but there is no definite proof incriminating this much-maligned creature as a necessary agent either in these or other diseases. The assassin-bug (*Triatoma megista*) is known to be the transmitting agent of Chagas disease to man in South America. The armadillo is the wild reservoir of this infection.

ENDOPARASITES

Endoparasites have been defined as those organisms which live parasitically for a greater part of their life within the body of their host. For convenience they may be considered under the following headings: (1) protozoa or one-celled organisms, (2) flatworms and (3) roundworms. There are so many thousands of these species that only a few can be considered.

Protozoa. Some of these lowly parasites are primitive and simple in their structure; others are complex and specialized. Among the former are the endamebas, while in the latter group are the malarial organisms.

The endamebas. These species live primarily in the digestive tract. Some live entirely in the intestinal lumen and feed only on food as it passes through the intestine. One type (*Endamoeba gingivalis*) is found associated with bacteria and spirochetes in pyorrheal infections of the gums. Another, *Endamoeba histolytica,* is a tissue parasite and causes definite ulcers in the large bowel. This latter species is common to man, several species of monkeys, the cat, the dog, the rat and the pig. In man it frequently produces dysentery.

Flagellates. There are two physiological groups of endoparasitic flagellates, those in the intestine and those in the blood stream and blood-forming organs. The former group are relatively innocuous; the latter are usually pathogenic. Among the latter are the dozens of species of trypanosomes, causing diseases in wild animals, also in cattle, horses, donkeys, sheep, camels, monkeys and man (sleeping sickness). Then there are the modified hemoflagellates (leishmanias) which cause cutaneous and visceral diseases in man and dogs.

Malarial parasites and related forms. There are three distinct species of malarial infection in man. In monkeys there are several types of malarial parasites. Other mammals also harbor parasites of this group, but it seems altogether likely that they are all distinct one from another. The piroplasms, anaplasms, etc., which infect red blood cells, are not known to infect man but constitute a serious group of infections in cattle, sheep, horses, camels, etc. Coccidia infest rabbits, sheep, cattle, hogs, dogs and cats and occasionally develop in man. Most of these coccidia are located in the walls of the intestines but in rabbits they infest the liver. Horses and cattle, camels and sheep are at times afflicted with a protozoan infection of the flesh known as *Sarcocystis,* and man has been reported to have incurred this disease.

Ciliates. There are several ciliated protozoa which live in the intestinal tract of mammals. Some of these are located in the stomachs of ruminants. The most widely known species, *Balantidium coli,* is a parasite of the large bowel of the hog, monkey and man. In man, at least, it is at times associated with a severe dysentery.

Flatworms. These forms consist of two types, tapeworms and flukes.

Tapeworms. There are many hundreds of species of tapeworms infesting mammals. The majority of these occur as adult, sexually mature forms attached to the intestinal wall of their host, but in some cases they are found in the larval state in other organs of the body. All species of mammals have tapeworms. Some of these worms are only a few millimeters in length while others are several meters long. The adult *Echinococcus* in the dog's intestine is an example of the first type; the human beef tapeworm, of the second type. In most instances the infection does not cause serious inconvenience to the host, but at times intestinal upsets, nervous disorders and profound anemias are attributed to these worms. All the tapeworms, with the exception of some of the dwarf species (*Hymenolepis* spp.), require at least one intermediate host. In many forms one mammal serves as the adult host and another as the larval or intermediate host. The following will serve as examples: *Taenia hydatigena,* dog (adult), ox, sheep, goat, pig (larval); *Taenia ovis,* dog (adult), sheep, goat (larval); *Taenia pisiformis,* dog (adult), rabbits (larval); *Taenia taeniformis,* cat (adult), rat (larval); *Taenia multiceps,* dog (adult), sheep, goat, ox, horse (larval); *Taenia serialis,* dog (adult), rabbit (larval); *Echinococcus granulosus,* dog (adult), sheep, ox, pig, man (larval). It will be seen from this series how important the dog is in spreading these infections, in which the larva is a far more serious pathogene than the adult worm.

Flukes. These worms are interesting but peculiar forms. All those found in mammals require some snail as a first intermediate host and some species require a second intermediate host as well. In certain types the mammal incurs the infection from consumption of herbage containing the larvae which have crawled out of their snail hosts and become encysted. This accounts for most of the fluke infections of cattle, sheep, hogs, camels, etc. Other mammals, such as dogs and cats and their wild relatives, beavers, martens, and man—all piscivorous animals—become infected from consumption of infested raw fish. The lung-fluke of wild felines, the pig, the dog and man is accounted for by consumption of infested raw crabs and crayfishes. The blood-flukes of horses, cattle, sheep, camels, mice and man invade the mammalian skin in their larval stage and migrate to the portal blood vessels.

Roundworms. The roundworms in mammals are legion. While the majority of them are found in the digestive tract, some important groups get into the muscles; others live in the blood and lymph spaces; still others have a predilection for the lungs, kidneys, etc. Most of these species have relatively simple life histories, but some require intermediate hosts. Those which get into the body via the mouth are introduced as a contamination of food or drink; those which use the skin as a portal of entry are usually introduced by the bite of a fly.[1] The "stomach-worm" (*Ascaris*), the whipworm and the pinworm are examples of the former type, while the filarial infections are representative of the latter type. The guinea-worm is an example of a most interesting type. It enters passively by accidental ingestion of water-fleas (*Cyclops* spp.) parasitized by the mature larval stage of the worm, and emerges through a skin puncture made by the gravid female worm at the time she is ready to discharge her progeny of wriggling larvae.

General Considerations

It may be inferred from a consideration of the foregoing types of animal

[1] The hookworm and related species constitute exceptions to this rule.

parasites of mammals that there is no strict line of cleavage between those forms found associated with wild mammals and those associated with mammals under domestication. Since all mammals were originally in the wild state and since parasitism undoubtedly antedates all known records, it is safe to assume that wild mammals were parasitized even at the time when they were emerging from their more lowly ancestors. Those species of parasites which have reached the nearest equilibrium with the tissues of their host, *i.e.*, those which cause least damage to the host, are possibly the forms that became associated earliest in this host-parasite relationship.

Undoubtedly in the past, as at present, epidemics with parasites have wiped out entire species of wild animals or have, at least, limited their distribution. However, animals in confinement are much more liable to infections of this kind. Man has acquired his animal parasites in three ways: (1) by eating the raw flesh of wild or domestic animals harboring the larval stage of the infection; (2) by skin and mouth contamination with stages of the parasite from mammalian sources, and (3) by insect bites, causing the introduction of parasites which have come from mammals to man. Of course many animal parasites of one host have failed to become adapted to other hosts exposed to infection. This fact has kept these infections more or less within limits. Likewise, certain species of parasites, while retaining their structural identity, have become physiologically different in different hosts, so that the parasite of one host is not interchangeable with that of another. This fact also tends to keep these infections within bounds.

Immunity reactions of mammals to animal parasites are much less complete than they are to bacteria. In fact, it seems likely that there is no complete immunity of any mammal to any animal parasite, although certain individuals manifest a partial immunity to malaria, to *Ascaris* infection and to hookworm infection. A relative age immunity has developed in the case of *Ascaris* in dogs, in that of the strongyle, *Haemonchus*, in sheep, and of the dwarf tapeworms in rodents and man.

The economic loss occasioned by animal parasite infections of mammals in the wild, in zoological gardens, and in cattle, sheep, pig and horse-breeding localities amounts to a physical drain on natural resources which is far greater than any intrinsic value that might be placed on it. Likewise, in human welfare, the illness and incapacity for work due to malaria, hookworm disease and other animal-parasite infection is too great and too wide-spread to be measured by monetary standards. Prevention of these infections requires, first of all, a knowledge of the life cycles of all the species of parasites involved; likewise, acquaintance with the weak points in the life cycle where the parasite may be most easily attacked. In the next place, it is necessary to utilize such methods as will be most practicable. Theoretically, the avoidance of contamination with infested excreta and screening from insects are the most common general methods of attack. Mass therapy is also an important line of procedure. Quarantine measures are designed to stop the spread of infections. Here, again, the problem can be solved only by an intimate acquaintance with the specific merits of the case.

From both a physiological and a practical view-point the animal infections of mammals constitute one of the most engaging group of problems in present-day zoology or medicine.

COLD PREVENTIVE WORK AT CORNELL UNIVERSITY

By Dr. D. F. SMILEY and Dr. G. F. MAUGHAN

DEPARTMENT OF HYGIENE DEPARTMENT OF PHYSIOLOGY

CORNELL UNIVERSITY

THE common cold and its complications has been the main disease cause of disability among our student body throughout the eighteen years for which figures are available. And the peak of the cold curve has invariably occurred each year sometime during the months of December, January, February or March.[1] In certain of these months, colds and their complications have been so frequent as to make up well over one quarter of the calls made upon our ten college physicians for advice or treatment.

The magnitude of the cold problem among the male students of Cornell University is somewhat shown in the accompanying chart (Chart 1).

CHART 1

RELATIVE NUMBER OF ACUTE INFECTIONS* OF THROAT AND RESPIRATORY SYSTEM FOR SPECIFIED YEARS

	Total consultations	Consulations for acute respiratory or throat infections	
		Number	Per cent.
1919–1920	13,619	2,392	17.4
1920–1921	13,280	1,475	11.0
1921–1922	16,655	2,409	14.4
1922–1923	16,832	2,894	17.2
1923–1924	17,852	2,453	13.7
1924–1925	21,360	3,057	14.3
1925–1926	18,798	3,614	19.2
1926–1927	16,999	2,714	15.9
1927–1928	18,913	3,177	16.7
1928–1929	17,306	3,035	17.5
1929–1930	15,256	2,116	13.8

* Diseases listed as acute infections of throat and respiratory system: "influenza" (cold and fever), Vincent's angina, acute rhinitis, acute bronchitis, acute pleurisy, acute tonsillitis, acute pharyngitis, acute otitis media, peritonsillar abscess, acute tracheitis, pneumonia and acute sinusitis.

Small wonder then that the prevention of colds has taken on for us something more than an academic interest!

THE COLD EPIDEMIC LIMITED TO A SMALL GROUP

In 1924 a questionnaire study[2] of 2,485 freshmen and sophomores showed the following distribution of colds according to frequency:

	Group 1,	Group 2,	Group 3,
	No cold or 1 a year	2 or 3 a year	4 or more a year
Men, per cent.	15.4	58.2	26.2
Women, per cent.	18.8	61.3	19.5
Average	17	60	23

In 1926 a similar questionnaire study[3] of 1,625 freshmen and sophomores showed the following distribution of colds according to frequency:

	Groups 1 and 2,	Group 3,
	Never more than 3 colds a year	4 or more a year
Men, per cent.	72.5	27.5
Women, per cent.	76.1	23 9
Average	74.3	25.7

Throughout the period, November 1, 1926, to April 3, 1927, we recorded the incidence of colds among 1,625 students who had classified themselves as having either three or less colds a year, or four

[1] "Seasonal Factors in the Incidence of the Acute Respiratory Infections," *Am. J. Hygiene*, vi, 5, 621–626, September, 1926.

[2] "A Study of the Acute Infections of the Throat and Respiratory System," *J. A. M. A.*, 82, 540–541, February 16, 1924.

[3] "A Study of the Weekly Incidence of Colds in Normal and in Cold-susceptible Groups throughout a Winter," *Am. J. Hygiene*, ix, 2, 477–479, March, 1929.

or more colds a year. Among the 468 normal (not more than three colds a year) women students and 732 normal men students throughout the twenty-two weeks in which colds were recorded, there was no week when more than 13 per cent. of the groups had a cold and no week when less than 3 per cent. had a cold. Among the 147 cold-susceptible women students and the 278 cold-susceptible men students, there were weeks when 60 to 62 per cent. of the groups had a cold and there was no week when less than 19 per cent. of the group had a cold.

A study[4] of the 815 male members of the entering class, in the fall of 1927, showed that 17.9 per cent. of them were cold susceptible (had four or more colds a year) and that same group had averaged 4.31 infectious diseases per person by college entrance as against an average of 3.68 infectious diseases per person, among the normal (never more than three colds a year) group.

From the above data we have concluded that there is one group of students (17.9 to 27.5 per cent.) who are unduly susceptible to all infectious diseases and particularly so to colds. And, furthermore, it is in this group we believe that our winter epidemics of colds occur, since the curve of colds in the normal group is flat and practically devoid of any epidemic peak.

The Cold Epidemic, Entirely a Winter Phenomenon

For the past 18 years there has been no winter when our student body has escaped having an epidemic of colds sometime during the dark, cold period between December 1 and March 31, though the peak for the year 1920–1921 was a very slight one.[1] There are many conditions which obtain in our student body during this winter period which do not obtain during the summer and which might quite conceivably lower the resistance of our cold-susceptible group *en masse*. The atmosphere of our lecture halls and recitation rooms throughout the winter months is apt to be hot, dry, quiet and considerably polluted by infective moisture droplets talked, coughed or sneezed out of the many throats. Windows are opened here and there and adequate mechanical systems of ventilation are in operation in a few of the more modern buildings, but in order to keep the feet warm and comfortable through the hour, the average lecturer or instructor has found that windows can be opened only very conservatively, if at all. Thus at the end of the hour the student not infrequently steps out abruptly from a classroom with a temperature of 70° Fahrenheit and a relative humidity of 25 per cent. into an outside atmosphere with a temperature of zero Fahrenheit and a relative humidity of 70 per cent. This marked difference in atmospheric conditions, the New York State Commission on Ventilation found, results in a paling, a swelling and non-resistant condition of the mucous membrane of the nose, as well as in a decrease in the mobilization powers of the "immune bodies" in the blood stream. A charting of cold incidence at Cornell against average temperature, month for month throughout the period, 1912–1913 to 1924–1925, showed a definite reciprocal relationship between the two.[1]

In spite of our earnest efforts to popularize the use of the "protective foodstuffs," such as milk, leafy vegetables and citrous fruits, a large number of college students still fail to include adequate amounts of these foods in their daily diet. As a result, it is not uncommon to find the alkaline reserve at a point we would consider low or low-normal. And when in midwinter the vegetables they do eat are largely canned ones and the milk comes

[4] "Cold-susceptibles *vs.* Normals, Physique and Past Medical History," *Am. J. Hygiene*, ix, 2, 473–476, March, 1929.

only from stall-fed cows, and the eggs from winter-housed chickens, a deficiency in vitamin intake sufficient to lower resistance to many types of infection is almost certain to occur.

The part that a high blood sugar plays in lowering resistance to colds is still not determined, but the frequency with which colds follow "candy sprees" in children and adults at Christmas time is at least suggestive.

A skin that receives little, if any, sunlight tends to become pale, rough and very sensitive to changes of temperature in the air about it. In such a skin very little vitamin D is formed from the irradiated ergosterol. Lack of sunlight in the dark winter months may, therefore, keep the skin hypersensitive to chilling and contribute to the vitamin deficiency, thus conceivably lowering the resistance to colds in two ways. A checking of cold incidence at Cornell against average hours of sunshine, month for month through the period 1912–1913 to 1924–1925, showed a definite reciprocal relationship between the two.[1]

We have, therefore, been led to conclude that some of the important factors responsible for the cold epidemics among our cold-susceptible students are faulty ventilation, faulty diet and lack of ultra-violet irradiation of the skin surface.

Previous Attempts at Control of Cold Epidemics

A large number of the experiments designed to control just one of the cold-causative factors enumerated above have given surprisingly favorable results. Thus the New York State Commission on Ventilation reports a uniformly decreased incidence of colds among school children whose schoolrooms are ventilated by the modern modified window method rather than by the mechanical method. Several workers report a decreased incidence of colds where the children's attention is rather continuously called through "no-cold campaigns" to such hygienic faults as sneezing or coughing with the mouth uncovered by a handkerchief. Other workers report that diets rich in the "protective food-stuffs," and particularly in butter, are very successful in reducing the incidence of colds. Dr. V. S. Cheney, of Chicago, states that it is frequently possible to prevent the occurrence of threatening colds by appropriate doses of alkali. At Cornell[5,6] through two winters, 1926–1927 and 1927–1928, groups of cold-susceptible students were given weekly irradiations of ultra-violet light which corresponded roughly with the amount of ultra-violet light which the average student would obtain from the sun's rays on his neck, face, hands and wrists in ordinary clothing in midsummer. The incidence of colds in the groups so irradiated was approximately 40 per cent. less than in similar groups of cold-susceptible students which were being followed but not irradiated.

Present Attempt at Control of Cold Epidemics

Beginning with the fall of 1929, the following measures were put into operation:

(1) Each freshman receives in his hygiene course as full an explanation as we can provide as to the importance of controlling the condition of the indoor air through proper regulation of heat and open windows, as to the importance of treating nose and throat secretions as extremely infective materials and as to the importance of including in the daily diet two to four glasses of milk, two helpings of leafy or fiber vegetables, one

[5] "The Effect of General Irradiation with Ultra-violet Light upon the Frequency of Colds," *J. Prev. Med.*, ii, 1, January, 1928.

[6] "Irradiations from a Quartz-mercury Vapor Lamp as a Factor in the Control of Common Colds," *Am. J. Hygiene*, ix, 2, 466–472, March, 1929.

helping of fruit, one or two salads, and very little candy or sweets.

(2) All those students who classify themselves as cold-susceptible (usually having colds four or more times a year) are urged to pay a nominal fee and join a "cold-prevention class," there to receive the following treatment:

(*A*) A fifteen-minute ultra-violet light bath is given once a week from October through December, twice a week from January through March, once a week again through April. (Solaria using Everready Sunshine carbon arcs, General Electric Type S1 lamps, and Cooper-Hewitt mercury arcs in corex D glass tubes and accommodating 150 students per hour have been installed.)

(*B*) Since we found that the alkaline reserve in a group of cold susceptibles was in many cases lower than that in a group of cold immunes, we have been issuing to the cold susceptibles joining the class one ounce packages of a powder composed of equal parts of sodium bicarbonate and magnesium carbonate flavored with oil of peppermint, with the directions to "take one teaspoonful in a glass of water twice a day for three days whenever the nose runs or the throat feels sore."

(*C*) In those persons whose colds continue to occur in spite of the above régime a careful study of the nose, throat and sinuses is made. Where a chronic sinusitis exists with the nose structurally normal, an antogenous vaccine is made up and given subcutaneously in 1 cc doses once a week through the year. Where sinuses, nose and throat seem normal, a mixed stock catarrhal vaccine is given in 1 cc doses once a week for a varying period. Where nasal obstruction, empyema of sinuses or chronic infection of tonsils demand it, operation is advised.

(*D*) A sheet of specific instructions concerning diet, alkalinization, ventilation, sleep and ultra-violet irradiation is given each member of the class.

Results in Cold-susceptible Group Treated

Each week during the period of treatment, each member of the cold-prevention class fills out a slip printed as follows:

Date

Name

Have you had a cold during the past week?

Yes

No

If "yes" was it mild ?

Severe ?

Each week also a control group of similar cold susceptibles, untreated and simply under observation in a weekly hygiene class, fills out a similar slip. The results, November, 1929, through January, 1930, were as follows:

	Total number of colds	Number mild colds	Number severe colds	Number colds apiece
100 cold-susceptible students under treatment	115	84	31	1.15
38 cold-susceptible male students untreated	76	54	22	2.00
Per cent. reduction, 42.5				

The results,[7] February, 1930, through April, 1930, were as follows:

	Total number of colds	Number with continuous colds	Number with no colds	Number of colds apiece
98 cold-susceptible male students under treatment	99	2	33	1.01
33 cold-susceptible male students untreated	80	2	2	2.42
Per cent. reduction, 58.26				

[7] "Further Observations on Control of Common Colds by Ultra-violet Rays," *Brit. J. Actinotherapy and Physiotherapy*, v, 6, 115, September, 1930.

Comment

The work so far has had to be largely limited to the male students, since the women students have not shown sufficient interest to pay the nominal fee and take the treatments in numbers large enough to be significant. Reasons for this may be, first, that women are not so much troubled by colds; second, it is possible that the women students object to the necessity of taking the treatments nude, even though in their own solarium operated by women and located in the women's medical adviser's office.

The results we obtained in the small group of women who joined the "cold-prevention class," February, 1930, through April, 1930, were as follows:

	Total number of colds	Number with continuous colds	Number with no colds	Number of colds apiece
15 cold-susceptible female students under treatment	26	1	3	1.73
6 cold-susceptible female students untreated .	13	0	0	2.16
Per cent. reduction, 19.9				

To expect at this early stage of the organized work (it is now only in its third term) to note a measurable reduction in the colds of the whole student body is to be too optimistic. If, however, we could popularize our "cold-prevention class" to the point where they would include 1,000 to 1,200 of our cold susceptibles instead of merely 150 to 300 of them, we have good theoretical grounds for believing that the cold epidemics in the whole student body would be considerably modified.

Conclusions

(1) Colds and their complications are our commonest disease cause of student disability.

(2) Cold epidemics occur largely in the 17.9 to 27.5 per cent. of students definitely cold susceptible and touch very little the normally resistant group.

(3) A combination of old and new methods applied to groups of cold-susceptible male students in our hands has resulted in a reduction of 42½ to 58 26 per cent. in cold incidence.

(4) Difficulty has been encountered in getting the cooperation of women students and in the very small group of cold-susceptible women who have joined the "cold-prevention class" a reduction of only 19.9 per cent, in cold incidence was noted in the first experiment.

(5) We have theoretical grounds for believing that attacking the colds in the cold-susceptible group will prove to be an effective way of modifying or averting the usual cold epidemics of our student body. We have as yet no positive evidence to present in confirmation of this belief.

PALMS OF THE CONTINENTAL UNITED STATES

By Dr. JOHN K. SMALL
NEW YORK BOTANICAL GARDEN

ALTHOUGH millions of people outside of the tropics are acquainted with palms, their acquaintance is limited largely to potted plants; and it is not, as one may well believe, under such circumstances that palms reveal themselves to be what they have so properly been termed: "Princes of the vegetable kingdom." While there are many kinds, it is true, that develop well in large greenhouses, most of the specimens grown indoors are puny; or even if well developed, their surroundings so detract from their true characteristics that much of their natural beauty is lost.

Only in the tropics or in the outlying areas of natural distribution in temperate regions, where nature has planted them and given them a chance to grow, either singly or *en masse,* does one get the true idea of the majesty of this unique and highly characteristic group of plants.

During the later geologic ages palms grew in most parts of North America, as is shown by the fossils preserved in the strata of the continent. Remains of the various organs, mostly leaves, have been found not only in temperate North America, but also as far north of the Arctic Circle as collectors have thus far penetrated. Owing chiefly to the firm substance of their tissues, moreover, the minutiae of some of these ancient palms have been preserved to us in the greatest detail. These palms of the North occurred mostly, if not wholly, in the later geologic ages, being most abundantly preserved in the strata of the Tertiary period, although they definitely appeared, developed and multiplied in the preceding period, the Cretaceous.

Palms were thus, apparently, much more widely distributed over the face of the earth in past geologic times than at present, but the number of different kinds living at any one time, perhaps, did not rival the aggregate existing today, which is approximately twelve hundred species. About the same number of species as are now living in the continental United States are recorded for the past ages by the fossil remains from all parts of North America.

In modern times there are two main centers of geographic distribution for palms—tropical America and tropical Asia. There is a minor center in tropical Africa.

Instead of extending into the present arctic regions as they formerly did, the northern geographic limits are now in the southern United States, southern Europe, Afghanistan and southern Japan, while the southern limit in America is about middle Chile, or, in other words, the geographic distribution is within 38° north latitude and 37° south latitude, in regions with an average temperature of 60° Fahrenheit or more, and a minimum rarely, if ever, below zero.

If palms were wide-spread in North America up to the ice ages, they were then pushed southward, perhaps beyond their present northern limits, for they may have regained some of the territory since the retreat of the ice. In origin palms were likely tropical. Hence those that populated temperate North America migrated northward. The ancestors of those now on the Atlantic seaboard would naturally have come from the West Indian region while those of the present

CABBAGE TREE (*SABAL PALMETTO*)

GROWING IN SAND AND FORMING A CABBAGE HAMMOCK ON INDIAN PRAIRIE WEST OF LAKE OKEECHOBEE, FLORIDA

BLUE STEM (*SABAL MINOR*)

GROWING IN ALLUVIUM IN SWAMP ALONG LITTLE RIVER, NORTHERN FLORIDA

NEEDLE PALM (*RHAPIDOPHYLLUM HYSTRIX*)
GROWING IN ALLUVIUM IN LITTLE RIVER SWAMP, NORTHERN FLORIDA

Californian species would have come through Mexico However, there is one palm mystery with us—the needle palm The present relatives of this unique palm are on the opposite side of the globe This condition, however, is not altogether unusual, for there are several herbaceous and woody plants in the flora of our Southeastern states thus isolated A record of the geologic, meteoric and biologic changes in the great hiatus during which such fundamental changes took place would be most instructive and entertaining[1]

Coconut Palm—*Cocos nucifera*
Buccaneer Palm, Hog Cabbage Palm, Sargent Palm—*Pseudophoenix vinifera.*
Royal Palm—*Roystonea regia.*
Date Palm—*Phoenix dactylifera.*
Cabbage Tree, Cabbage Palmetto, Cabbage Palm, Tree Palmetto, Swamp Pamletto—*Sabal Palmetto.*
James' Palmetto—*Sabal Jamesiana.*
Palmetto Palm, Texan Palmetto, Texas Cabbage Tree—*Sabal texana.*
Scrub Palmetto, Sand-hill Palmetto—Sabal *Etonia*
Blue Stem, Dwarf Palmetto—*Sabal minor.*
Palmetto-with a stem, Bayou Palmetto—*Sabal Deeringiana.*
Saw Palmetto—*Serenoa repens*
Fanleaf Palm, Desert Palm, Washington Palm—*Washingtonia filifera*
Silk top Thatch—*Thrinax parviflora.*
Brittle Thatch—*Thrinax microcarpa.*
Silver Palm—*Coccothrinax argentea*
Saw Cabbage Palm, Spanish-top, Cuban Palm—*Paurotis Wrightii.*
Needle Palm, Blue Palmetto *Rhapidophyllum hystrix.*

The history of the palms of the continental United States covers more than four centuries. The earliest reference seems to be embodied in the "Rio de las Palmas" on the map of Alberto Cantino[2] This Rio de las Palmas is with-

[1] The following list gives the botanical names of the palms of the continental United States and their equivalent common names The latter are used throughout this article

[2] Though to the famous Ponce de Léon goes the credit of being the first European to land on the shores of the North American continent, we are confronted with two ancient and authentic maps, one dated 1502 and a second 1508, eleven and again five years before 1513 when

out much doubt intended to represent the now international Rio Grande If this is so, the palmetto palm or Texan cabbage tree, would be the first of our palms to be referred to, though indirectly On the other hand, the latest native genus to come to light within our boundaries was the saw-cabbage palm, which was discovered in southern Florida as recently as 1888.

There seems to have been little recorded concerning North American palms, at least in English literature, between 1500 and 1700 After the beginning of the eighteenth century references to these plants became more numerous, and the following palms were added to our recorded flora in the order cited—saw palmetto, royal palm, fanleaf palm, needle palm, coconut, silver palm, thatch palm, buccaneer palm, saw-cabbage palm and date palm.

the famous knight of Léon arrived in search of the Fountain of Eternal Youth Some one, name, nationality, and date unknown, had previously made a voyage to the coast of Mexico, around Florida and up the Atlantic Coast as evidenced by the oldest map, dated 1502, known as the Alberto Cantino map - *Robert Ranson.*

To-day seventeen different kinds of palms are known to grow naturally in the continental United States—four feather palms and thirteen fan palms The former group seems to represent a more primitive type, at least as indicated by the structure of the leaf, in which the divisions are arranged along the sides of an elongate axis or rachis This group includes four of our palms. Arranged in their biological sequence, they are buccaneer or hog-cabbage, coconut, royal and date palms In the fan palms the leaf axis or rachis beyond the petiole is wholly or partly lost In this case there are no separate divisions of the leaf but there is a blade with the veins arising palmately from the tip of the petiole or pseudopalmately (or subpin-

SAW PALMETTO (*SERENOA REPENS*)

WITH PROSTRATE CREEPING STEMS, GROWING ON COASTAL SAND DUNES, CAPE CANAVERAL REGION, FLORIDA.

SAW PALMETTO (*SERENOA REPENS*) WITH ERECT STEMS, GROWING IN SAND IN PINE-LANDS, EAST OF TAMPA BAY, FLORIDA.

nately) from the more or less abbreviated midrib, which represents the remains of the rachis of the leaves of the pinnate type, and prolonged into lobes or segments beyond the body of the blade. Consequently the fan palms may be classed into two groups which may be designated. Palmatae and Pinnati-palmatae. The latter group embraces the cabbage trees or palmettos, the fanleaf, the saw-cabbage and the needle palms. The former group, or that of the truly palmate or flabellate palms, comprises the saw palmetto, the thatch and the silver palms.

The geographic distribution of the living palms of the United States is almost identical with that of the flowering epiphytes or air plants. The state of Virginia, however, is not invaded by the palms, while Arkansas in the East and California in the West must be added to the credit of the palms alone. The geographic distribution may be briefly stated thus: the southeastern United in Arkansas, Louisana and Texas, and in southern California. In considering the geographic distribution of the palms in relation to the various states, it is understood, of course, that the political areas are not usually made on the basis of biologic or geologic boundaries. However, they are definite and well fixed in people's minds and serve to indicate latitudinal and longitudinal distribution. It may be of interest to record here that our palms are naturally confined to the Atlantic and the Gulf Coastal plains with two minor exceptions. These will be referred to further on.

The most northern locality for living native palms in North America is Cape Hatteras, North Carolina, although the palm region in southern California is a close second.

In modern times, palms would probably be able to grow naturally farther

DATE PALM (*PHOENIX DACTYLIFERA*) WITH A COCONUT PALM AT LEFT, GROWING IN SAND AND MARL ALONG BAY BISCAYNE, FLORIDA.

northward along the Atlantic coast if it were not for the abrupt angle in the coast line of North Carolina. Between Georgia and Cape Hatteras the coast line runs in a northeasterly direction, so that the coastal sands and dunes have a warm southeastern exposure. At a point about thirty miles north of Cape Hatteras, however, the coast line turns abruptly to the northwest, and thus north of the Hatteras region the shore has a northeastern exposure. Consequently a great deal of the warmth derived from the angle of the sun's rays on the land south of Cape Hatteras, as well as the effect of the warm air from the great expanse of heated water lying between the coasts of the Carolinas and the Gulf Stream and the West Indies, is lost to the coastal region north of Cape Hatteras. Although only on the edge of one of the major palm regions, the following notes on the palm association of the southern United States will be a revelation to some and of interest to many plant lovers.

SILK-TOP THATCH (*THRINAX PARVIFLORA*)

GROWING ON CORAL LIMESTONE IN HAMMOCK ON RACHEL KEY, FLORIDA.

SILVER PALM (*COCCOTHRINAX ARGENTEA*)

MATURE, GROWING ON OOLITIC LIMESTONE IN PINE-PALM LANDS OF BIG PINE KEY, FLORIDA.

Taking up the geographic distribution by states, we find that the only palms known to grow naturally in North Carolina are the cabbage tree and the blue stem. Passing southward, we find the same species repeated in South Carolina and also two additional ones in the extreme southern part of that State. The latter are the needle palm and the saw palmetto. In Georgia are found the same four palms that occur in South Carolina. To sum up: there are four different

COCONUT PALM (*COCOS NUCIFERA*)
GROWING IN GROOVE IN SAND ALONG BAY BISCAYNE, FLORIDA.

palms, the cabbage tree, the blue stem, the needle palm, and the saw palmetto, together representing three genera, in the Atlantic Coastal Plain north of Florida.

The cabbage tree now ranges farther north than any other of our species. Curiously enough, however, it is absent from the Gulf Coast westward of Saint Andrew's Bay, Florida, although conditions along the Gulf of Mexico seem to be favorable for its growth, at least nearly or quite as much so as those that obtain along the Atlantic Coast north of Florida. Its absence from the Gulf Coast may be occasioned by cold storms that sweep down through the Mississippi Valley, where there is less high land and no mountain chains to temper them as there are back of the Atlantic seaboard

However, this well-marked, north-south extension of range may be the result of the passage of migratory birds, plus favorable temperature and other climatic conditions. Peninsular Florida is, and perhaps was formerly, at least in recent geologic time, the center of the geographic distribution of the cabbage trees. The general course of flight of migratory birds is north and south and not east and west. Birds may have carried the seeds of this palm northward. Although they may retain seeds in their alimentary canal but a short time, year after year they may have carried the seed farther and farther northward in the Coastal Plain. By slow stages of progress the palm could thus have gradually accommodated itself to a cooler and more changeable climate until it reached its limit of endurance at Cape Hatteras. This seemed good theory even when it was still pure supposition, but recently an actual case of the migration of two of our native palms has come to our notice. Thus, the northern geographic limit of the silver palm until lately was in the vicinity of the Miami River on the Everglade Keys in southern peninsular Florida, but within the past relatively few years the northern limit has actually been extended over seventy miles, or more than a hundred miles northward of its Floridian center of development.

The fruits of this palm are black and meaty, and are esteemed as food not only by various birds but by other animals as

well. When a coastwise navigation canal was dredged northward from the upper end of Bay Biscayne, sand banks were thrown up on one side or another of the waterway. These banks, undisturbed, soon became clothed with herbs, shrubs and trees, as a result of the various methods of seed dispersal, representing both local plants and those foreign to the region. Among the latter is the silver palm, found on the embankments and apparently nowhere else in the region. Thus, it is fair to believe that the migratory birds bringing the seeds northward, either follow the course of the inland waterway closely in their flight, or that seeds dropped in neighboring parts where there is little country suitable for their growth do not germinate or, at least, do not survive after germination.

Closely following this, another equally interesting discovery was made. The silk-top thatch was found growing in the dense tropical plant association on the coastal dunes between Delray and Palm Beach. These palms had attained no great size—apparently of recent introduction, their advent there was evidently due to the agency of birds. The sand-dune hammocks along the entire eastern coast of Florida are exceedingly interesting and as yet but little explored and studied. In some places the woody vegetation is wind-worn and sand-worn, in other places, especially on aboriginal village sites not directly exposed to the ocean, many of the trees are of great size. That birds and also mammals plant seeds of their food plants thereabouts is evidenced by the palms, figs, cacti, and various berry-bearing shrubs that spring up and survive for a time on the large horizontal limbs and in decaying knot-holes remote from the source of supply of their seeds.

Of course the higher latitude is against

SILVER PALM (*COCCOTHRINAX ARGENTEA*)

JUVENILE, GROWING IN SAND, MIAMI, FLORIDA.

ROYAL PALM (*ROYSTONEA REGIA*)
GROWING IN MARL IN ROYAL PALM HAMMOCK IN THE BIG CYPRESS SWAMP, FLORIDA.

the natural development of this tender tropical palm northward, but the tempering effects of the canal, the lagoons, the marshes, and the nearby ocean, although they are slight, may be sufficient to enable the palm growing directly on the warm banks to survive the cold spells of the winters.

On the other hand, some of our palms are retreating to a highly circumscribed area. Take the royal palm for an example. William Bartram found this palm far "up" (really down) the Saint John's River—between Lake George and Lake Dexter—shortly after the middle of the eighteenth century, for he records that:

> The palm trees here seem to be of a different species from the cabbage tree; their straight trunks are sixty, eighty, or ninety feet high, with a beautiful taper, of a bright ash colour, until within six or seven feet of the top, where it is a fine green colour, crowned with an orb of rich green plumed leaves.

To-day there are no royal palms growing naturally within two hundred and fifty miles of Bartram's recorded locality. Furthermore, during the "freezes" of 1894 and 1895, the three isolated royal palms growing in a hammock in the Big Cypress Swamp near the settlement of Everglades were killed, and the species thus exterminated in that immediate region by the wiping out of the colony.

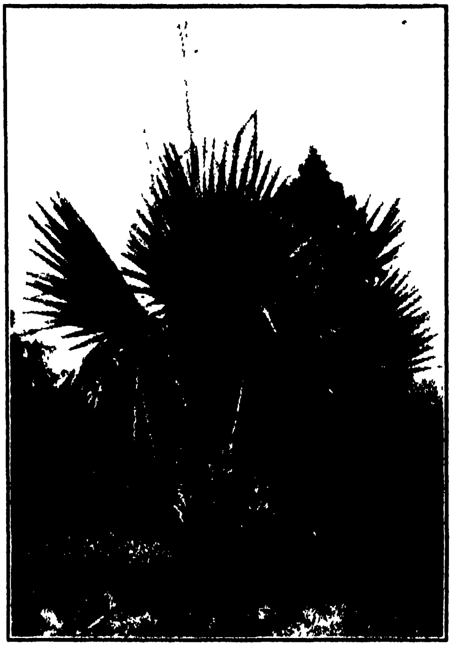
Before considering our palm *El Dorado* we will approach it by another route, from west to east. Thus, taking up the Gulf States and beginning at the western extremity of the range: In Texas, as in the case of North Carolina, we first find a cabbage tree -the pal-

BUCCANEER PALM (*PSEUDOPHOENIX VINIFERA*)
GROWING ON CORAL LIMESTONE IN HAMMOCK OF ELLIOTT'S KEY, FLORIDA.

metto palm or Texas cabbage tree—in the extreme southern tip of the state. This palm represents the southern limit of distribution in the western Gulf States, just as its relative the cabbage tree represents the northern limit of distribution in the Atlantic States Farther north in the Coastal Plain of Texas the blue stem, which was also associated with a cabbage tree in North Carolina, appears. In all, there are then but two palms native in Texas In Louisiana the number of species is three, the palmetto palm has dropped out, and the palmetto-with-a-stem or the bayou palmetto is associated with the blue stem, and the saw palmetto appears east of the Mississippi River. The blue stem occurs also in southeastern Arkansas

BRITTLE THATCH (*THRINAX MICROCARPA*)

GROWING ON OOLITIC LIMESTONE IN PINE-PALM LANDS ON BIG PINE KEY, FLORIDA.



PALMETTO-WITH-A-STEM (*SABAL DEERINGIANA*)

GROWING IN GUMBO IN SWAMP ALONG LAKE PONTCHARTRAIN, LOUISIANA.

Passing eastward from the delta of the Mississippi River, the blue stem and the saw palmetto are retained and thus the State of Mississippi, like its neighbor, Alabama, has three kinds of palms, the blue stem, the needle palm and the saw palmetto

Here it is interesting to notice that we find the only exception in the eastern states to palms occurring outside the Coastal Plain. The first and second palms—the blue stem and the needle palm just mentioned—occur a little way north of the fall line in Alabama, while the blue stem extends over on the edge of the Edwards Plateau in Texas. These extra-limital, so to speak, cases of distribution are interesting when we realize that with these exceptions the palms not only are confined to the Coastal Plain, but that they, for the most part, grow in the lower parts of that region.

PALMETTO PALM (*SABAL TEXANA*)

GROWING IN CLAY AND FORMING A GROVE ALONG THE LOWER RIO GRANDE, TEXAS.

One state in the East remains to be considered; it is both an Atlantic state and a Gulf state, namely, Florida. In fact floristically it is largely "a law unto itself" among the contiguous states. It is no wonder that Florida with its unique geographic position and long peninsula, flanked on both sides by vast bodies of warm water, and whose southern extremity is situated farther south than any other part of the continental United States and continuously bathed with the tropical waters of the Gulf Stream, is naturally and preeminently the State of Palms. For the same reasons, it is the banner state for the epiphytic ferns, as well as for the flowering air plants. Within its boundaries may be found every palm already mentioned, except the palmetto palm and the bayou palmetto, and in addition, ten other species. All the species of palms within the geographic limits covered by this article but two are native. The coconut palm was introduced into Florida after its advent in the New World through the agency of the early Spanish expeditioners, either through natural or artificial channels, while the date palm has been introduced through cultivation and the scattering of seeds. Of the eight native genera, one—the needle palm—is limited to the southeastern United States, while seven others have species growing naturally in the West Indies. Curiously enough, none of the species growing naturally in Florida occur in the continental tropics, except the now widely distributed and extensively cultivated coconut palm.

The following coincidence is interesting: In the case of the flowering air plants, whose geographic distribution is almost identical with that of the palms in the eastern United States, all except one endemic species of southern Texas occur in Florida; likewise all the species of palms in the eastern United States except one endemic kind in southern Texas and also one in Louisiana, occur

in Florida! Furthermore, the palms, like the epiphytes, are evergreen.

Two of the species - the needle palm and the blue stem -that grow in other states occur only in northern Florida and in the northern part of the peninsula, while the other two—the cabbage tree and the saw palmetto—extend southward not only to the end of the peninsula, but beyond it to the lower Florida Keys, as recent exploration has demonstrated. The endemic species of Florida are the scrub palmetto and the James' palmetto. The former occurs from the northern part of the lake region to the southern part of the peninsula, while the latter ranges from the Everglade Keys to the southern end of the lake region.

The other eight species that do not grow naturally north of Florida are confined to the tropical and adjacent subtropical parts of the State. They are the silk-top thatch, the brittle thatch, and the silver, the saw-cabbage, the royal, the hog-cabbage, the coconut and the date palms.

The hog-cabbage palm has of late years been erroneously reported as exterminated in Florida. It grows naturally also on the other side of the Gulf Stream, both in the Bahamas and on the Cuban Keys, and it has rather recently been rediscovered in Santo Domingo.

Among the other five native species the two thatch palms and the silver palm grow both on the Florida Keys and on the nearby mainland, but nearly or quite within the bounds of the tropical region. The saw-cabbage and the royal palms do not grow naturally on the Florida Keys, but occur in the tropical portion of the peninsula and the adjacent subtropical parts south of a line between Arch Creek on the Atlantic Coast and Cape Romano on the Gulf Coast. Whether the geographic distribution of the royal palm is wholly or only in part natural will be discussed further on; but it may be said in passing that it is evidently native in most places where it is now found, although in a few localities it may have been introduced by the

SCRUB PALMETTO (*SABAL ETONIA*)

GROWING IN SAND AND SCATTERED OVER THE SANDHILLS OF THE LAKE REGION, FLORIDA.

JAMES' PALMETTO (*SABAL JAMESII*)
GROWING IN SAND IN HAMMOCK ON THE EVERGLADE KEYS, FLORIDA.

aborigines before the coming of the white man.

The remaining palms to be considered grow in a region far distant from that already described; they are the fanleaf or desert palms of the Pacific slope[3] These plants are the only conspicuous exception in the parallel of the geographic distribution of the palms of the United States and that of the flowering epiphytes.

Following is a list of the palms of North America north of the West Indies and of Mexico, with indications of their geographic distribution and uses:

COCONUT PALM—Southern Florida—Native of Polynesia and the East Indian Archipelago, whence it was brought to the western coast of Tropical America and established perhaps within half a century after the discovery of the New World by Columbus Now widely naturalized in the tropics Extensively introduced into southern Florida in the earlier part of the second half of the past century Cultivated in many parts of the tropics for its fibers, fruits, and oil, and for ornament

BUCCANEER PALM, HOG-CABBAGE PALM, SARGENT PALM—Upper Florida Keys (W. I.). Cultivated for ornament. Stems used as food for animals. The sap was formerly converted into an alcoholic drink. The fruits are used for fattening hogs. The bud is edible.

ROYAL PALM—Southern peninsular Florida; perhaps formerly more widely distributed in the peninsula (W. I.). Cultivated for ornament. The spathes are employed for packing or wrapping various objects. The fruits are used for fattening hogs.

[3] Apparently only one of these palms is native in California. The second known species, *W. robusta*, native in Lower California, is extensively cultivated in southern California and may be naturalized there. *W. filifera*, or perhaps a third species, has been discovered in western Arizona.

DATE PALM—Southern Florida. Introduced from Africa and Asia where it has been cultivated from prehistoric times. The tree figured in symbolism, the fruits furnished a staple food, and the leaves ecclesiastical paraphernalia. It is grown in Florida for ornament and occasionally for food.

CABBAGE TREE, CABBAGE PALMETTO, CABBAGE PALM, TREE PALMETTO, SWAMP PALMETTO—North Carolina, South Carolina, Georgia, Florida (W. I.). Cultivated for ornament. Bud used for food. Leaf fibers woven into braid for making hats and rope. Stems used for timbers, posts and piles. The leaves are commonly employed as a thatch

JAMES' PALMETTO—Southern peninsular Florida (Endemic). Occasionally planted for ornament The fruits are eaten by birds and mammals.

PALMETTO PALM, TEXAN PALMETTO, TEXAS CABBAGE TREE—Southern Texas (Endemic). Uses same as those of *Sabal Palmetto*.

SCRUB PALMETTO—Peninsular Florida (Endemic) Bud used for food. Fruits eaten by hogs.

BLUE STEM, DWARF PALMETTO—North Carolina, South Carolina, Georgia, Arkansas, Texas, Louisiana, Mississippi, Alabama, Florida (Limited to the United States). Cultivated for ornament Leaf fiber woven into braid for making hats. Leaves are used for thatch and are eaten by cattle Hogs eat the fruits.

PALMETTO WITH A STEM, BAYOU PALMETTO—Southern Louisiana (Endemic). Occasionally planted for ornament. The leaves are used for decorations. The fruits are eaten by birds and mammals.

SAW PALMETTO—South Carolina, Georgia, Texas(?), Louisiana, Mississippi, Alabama, Florida (Limited to the United States). Stems a source of tannic acid; also used for making brushes The leaves are prepared for decorative purposes. The fruits are used medicinally and for making a popular drink. They are much sought after by hogs and formerly were a staple food of the aborigines. The bud is edible.

FANLEAF PALM, DESERT PALM, WASHINGTON PALM—Southern California (Lower California). Cultivated in America and Europe for ornament. Stem used for timber, contains also much salt and sugar. Fruits are used for food by Indians.

SILK-TOP THATCH, THATCH PALM—Southern Florida (W. I.). Cultivated for ornament. Leaf fiber woven into braid for making hats Stems used in construction. The leaves of this and the following species of *Thrinax* are prepared for indoor decorations.

BRITTLE THATCH—Southern Florida (W. I.). Cultivated for ornament. Leaf fiber woven into braid for making hats. Stems used for construction.

SILVER PALM, SILVER-THATCH PALM—Southern Florida, geographic range increasing (W. I.). Cultivated for ornament. Stems locally used for construction.

SAW-CABBAGE PALM, SPANISH TOP, CUBAN PALM—Southern peninsular Florida (W. I.). Cultivated for ornament. Stems used in construction.

NEEDLE PALM, BLUE PALMETTO—South Carolina, Georgia, Alabama, Mississippi, Florida (Confined to the United States). Sometimes cultivated for ornament.

In addition to the above cited uses, the fruits of all our palms are food for various birds and mammals. The leaves, too, are gathered and shipped to distant points for symbols in traditional ecclesiastical ceremonies, applicable both to the living and to the dead, inherited directly or indirectly from ancient pagan peoples.

Considering their relative conspicuousness, our native palms were slow in securing recognition in our botanical records. The only palms now growing wild in the United States known to Linnaeus were the coconut and the date palms, both, however, introduced plants. Two additional ones came to the attention of European botanists or European plant collectors as early as the beginning of the last century, and, curiously enough, only these four were known to botanists as late as the seventies of the nineteenth century. Even as late as 1880 a note in the "Botany of California"[4] states that only "four species of

[4] "Botany of California." Ed 2 2. 1880. The authors of that work were ignorant of any of our pinnate-leaved palms, for they wrote: "The United States genera all belong to the group *Coryphinae* or *Sabalinae*, distinguished by their fan-shaped leaves and perfect flowers " The coconut palm had evidently been known in southern Florida for many years previous. The genus *Roystonea* was definitely discovered there about three years previous to the publication of the work in question, while

WASHINGTON PALM (*WASHINGTONIA FILIFERA*)

JUVENILE, GROWING IN GRANITIC SOIL IN GROVE OF A THOUSAND PALMS NEAR INDIO, CALIFORNIA.

palms are found on the Atlantic coast"—of course, meaning the Atlantic seaboard.

During the last decade of the nineteenth century, exploration in southern Florida brought additional species to light, so that now we know definitely of sixteen different kinds of palms growing without cultivation in the Coastal Plain between Cape Hatteras, in North Carolina, and the mouth of the Rio Grande in Texas. The additional palm or the seventeenth species is the fanleaf palm of California. Although the Pacific slope can claim only one native palm, it can boast of the largest—the giant of our palms. The royal palm in the East may rival the fanleaf palm in the West in height, but it lacks the massiveness of the trunk.

The origin of our native palms is an interesting problem. On the Atlantic side of the continent the genera *Pseudophoenix*, *Roystonea*, *Sabal*, *Thrinax*, *Coccothrinax*, and *Paurotis* indicate an Antillean origin, while on the Pacific side *Washingtonia* is related to Mexican and Pacific forms. The two endemic genera, represented by the saw palmetto and the needle palm, are especially interesting. The former is related to Antillean types, while the relatives of *Rhaphidophyllum* are far off on the shores of Asia In structure and habit it is unique in our flora. It is a repre-

SAW-CABBAGE PALM (*PAUROTIS WRIGHTII*)

GROWING IN MARL IN HAMMOCK ALONG CUTHBERT LAKE, CAPE SABLE REGION, FLORIDA.

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the third pinnate-leaved palm, *Pseudophoenix*, was not discovered in Florida until six years after its publication.

sentative of an ancient and apparently now largely extinct arrangement of plants in which its sometime associates, *Tumion taxifolium, Taxus floridana,* and *Croomia pauciflora* flourished, but which to-day exist as mere remnants among a strange plant association with their closest relatives thousands of miles away.

Truly this is a notable representation of an aristocratic family among plants, primarily tropical, flourishing in a region where temperate, mild conditions prevail. A group of plants whose timber, foliage, fruits and sap in themselves are sufficient for supplying the necessities, shelter, clothing, food and drink for a primitive people. Likewise, the palms, if not a necessity to a civilized people, furnish many objects of convenience and derivatives of great utility.

MODERN YOUTH AND THE RESEARCH SPIRIT

By Professor J. O. HERTZLER

UNIVERSITY OF NEBRASKA

I

THE tempo of modern life is breathtaking. Kaleidoscopic changes are occurring, and unsettling developments confront us continually Our material civilization is ever changing. New social needs and problems are evident on every hand. Cherished and long-standing social, ethical, economic and political view-points and institutions are being criticized and modified or even abandoned. The world of arts and the spiritual life are in upheaval. New challenges must be faced and new adjustments of all kinds must be made continually if the individual is to be a reasonably intelligent and successful participant in life There is no place in this modern world for the person who acts only on the basis of instinct, habit and routine or rule of thumb.

Any education worthy of the name, therefore, must consist of more than an accumulation of standardized facts and the acquisition of the contemporary culture. We are also beginning to see that it should give more than the mastery of some technique, more than mere preparation for meeting the conventional requirements of life at the moment.

Education to-day must develop the powers that will give the individual facility to use the acquired knowledge and techniques But he must have not only faculty and versatility; he requires also the *attitudes* that will enable him to get at truth, orient himself to it and apply it in the future by himself. Education must produce a capacity for interpretation that will enable him to make a workable mental and social adjustment to the trends of a changing world. It must awaken in him an insight and an outlook, and prepare him for intellectual pioneering

Most of the intelligent citizenry and apparently many of the educational authorities as well are unaware of what is happening to our present-day students in the way of making them mere routiners and followers of vocations. The contention of this paper is that our colleges and universities are grievously failing to meet one of their greatest obligations if they do not give the students and, through them, the population at large, the research spirit.

II

This research spirit is the method of thinking and the attitude of science Of first rank importance in it is the desire to know The person with the research spirit has a boundless, insatiable curiosity, an abiding passion for facts and for understanding the relationships among them. He does not knowingly traffic with untruth or half-truth, nor what he surmises would destroy truth.

To make this discovery of truth possible several other attitudes are essential. He seeks to develop a meticulous precision of observation, study, thought and statement. To be sure that he is fairly facing all sides he is tolerant, impartial and devoid of sentimentality. He is willing to recognize and examine divergent claims. Dogmatism is foreign to him, and he insists that all that claims to be fact or truth demonstrate its quality in the forum of life.

His attitude is always critical, even skeptical. He never thinks that the evidence is all in. The most important witnesses may still be in waiting, and will continue so till he learns how to call

them in. He questions all dogmas and theories, all precedents and traditions, all solutions and methods until he has had opportunity to examine them or inform himself as fully as possible respecting them. He is somewhat skeptical of all authority and permits himself no sanctities save truth and reality. He is suspicious of strong partisanship, of all that smacks of propaganda, all strenuously pressed claims and sugar-coated ideas. He is critical of all that is old, feeling that it may be static or archaic, and of all that is new because it may be untried or premature. But he will accept either old or new if it meets the tests. With Paul of Tarsus, he would test all things and hold fast that which proves to be good. His is an implicit willingness to follow free inquiry to an unwelcome conclusion.

The individual with the research spirit is composed when confronted by change, however revolutionary it may be; in fact, being mindful that everything is in a state of continual flux, he anticipates change. He adjusts himself without panic or fear, for he knows that the truth that yet lies hidden will be gradually revealed and may, as history lucidly teaches, overturn many or all existing conclusions and methods.

It is a spirit that, while keeping the individual humble before truth, does not permit an attitude of resignation, defeat or indifference. Neither does it allow complacence. Inherent in it is hope of solution and confidence in reason.

Patience is also innate here. Investigation is not hurried along to a conclusion. The best truth available at the moment is deliberately sought. But when he is sure of his truth the worker hesitates not a moment in putting it into effect. For truth is no end in itself, in his opinion, but a means to fulness of life and to social progress.

There is also inherent in the research spirit a discipline which produces facility in analysis, interpretation and conclusion. If the individual is without bias and has a sufficiency of truth, he sees fact follow fact in inexorable sequence to an inerrant and inevitable conclusion. He develops a logical method of thought which enables him to penetrate confusion, discover untruth and lay bare facts which he can then use effectively to make an approach to solutions. The individual learns to think clearly, see straight and act with judgment.

Finally the research spirit develops in the individual new powers of imagination and inventiveness. Experience in connecting fact with fact and reasoning from cause to effect enables him to transcend the existing and contemporaneous and pass logically in his mind to the necessary but non-existent, to the next step, even the remote future step. The research ideal stretches the mind and exalts the spirit as it carries man farther on his upward flight. It *is* the creative spirit.

Thus the research spirit is the philosophical essence of scientific procedure. It is an outlook on life tempered and disciplined by the scientific method of arriving at facts. It is realistic in its approach to problems, yet idealistic and even spiritual in its interpretations and solutions. The writer's thesis is that it offers an eminently desirable, even indispensable, philosophy of life for men at large, but especially for modern youth in this more or less chaotic and disillusioned age. It is not offered as a cure-all, for it is by no means all the young people need. It must also be remembered that not all people engaged in research are models of the research spirit. Some of the most bigoted and mentally insecure persons are scientists of competence in their own special field; but their research spirit is applied *only in that field.* To have its fullest significance the individual must utilize it in *all* his thinking. Itself a by-product of

this age, it is also one of its important remedies.

The writer is a social scientist and has also for twelve years been the teacher, friend and father confessor of university students. What does he see, as he looks out on life, that leads him to think that the research spirit should be developed as far as possible in students to aid them in their life problems?

III

Ours is an intricate mechanical world full of ever-multiplying devices, attachments and appliances. They are increasing the nervous tension and occupational hazards of millions. They touch almost every moment and aspect of our lives, making them more complex and artificial. They have claimed our bodies and our time. Shall they also claim our souls?

This is a shrinking world as well as a mechanical one. The recent developments in transportation and communication have suddenly thrust upon the individual a vast and unprecedented number and variety of culture elements from every corner of the earth. The relocation or breakdown of political boundaries and of economic and racial barriers since the war has also accentuated and brought to the consciousness of the rank and file a whole series of new, danger-laden problems. The individual must withstand the shock of contact with all these new culture elements and problems, choose among them, maintain his mental, moral and spiritual balance and arrive at workable conclusions.

This is also a world that is filling up. The world population has doubled in the last century and is now increasing at an unprecedented rate. This makes social relationships ever more complex and impersonal, and anti-social action becomes easier. It imposes new obligations upon us as consumers of resources, as users of machines and as potential progenitors of future generations. It causes the division of labor to become more extensive and intricate, increasing the mutual dependence of individuals, classes and nations. Furthermore, as numbers increase in a world of limited area and diminishing returns, international economic rivalry results and from this arises a never-ending series of crises that continually threaten and periodically disturb the peace of the world. To avoid war we need the research spirit above all, for not superficial but final and fundamental remedies must be found that will check it at its source, namely, human reproduction.

In every country modern government has become very complex as it has had to assume new problems. In America, especially, its details have come to be so numerous, so involved and so technical that the average citizen does not and can not know about them. When decisions must be made he takes refuge in his party creed and swallows his party's catchwords and slogans without compunction. Since he thinks little for himself he becomes a fundamentalist in politics, using the doctrines of government established by an agricultural and stage-coach people, and accepting the Constitution in its textual literalness of 1790 and not in its essential interpretations of 1930. He acts on the basis of stereotypes or of a public opinion manufactured by propaganda and counter-propaganda working upon his traditions, prejudices, aversions or his inertia. And finally, if he votes at all, he is usually one of only about 30 per cent. of the citizens entitled to vote. The future success of democracy demands willing, informed and self-possessed citizens, able to penetrate to the bases of political action and capable of participating independently and intelligently.

Because of the absence of an effective public opinion and sound individual information or conviction, and yet being confronted in this democracy by a mass of problems crying for treatment, we

Americans, especially, through our legislators, have taken the easiest way and have resorted to laws as means of coping with them. The consequence is that our laws are so numerous that we can know almost none of them, we have little energy for or interest in enforcing them and have developed a growing disrespect for all laws. Our very plethora of laws has made us lawless.

Because of these problems growing out of the complexity and diversity of modern life, the requirements of social and rational action are more numerous and frequent than ever before. Relatively, however, the tried and established means and materials for coping with them are fewer and less suitable than ever before. Hence, what is needed among the rank and file is a set of attitudes that make us socially alert, that enable us to evaluate social situations and recognize anti-social acts.

IV

The enormous and continuous growth of wealth presents challenges. There now is in America the greatest per capita wealth the world has ever known. But we have so mismanaged as to give unprecedented luxury to a few; we have intensified the struggle for a living, increased our waste and produced a serious unrest.

We have erred in another way. Economic goods have become ends in themselves. Modern business has engaged in ubiquitous advertising, the essence of whose appeal is that you can not be intelligent or progressive unless you purchase every new product on the market and display it. Its maxim seems to be, "Set your hearts on the things of this world." This has made a kind of universal prodigality obligatory among all classes. Spiritual values, true culture, appreciation of real beauty, service of the good, true and abiding cede to the tawdry display of dollar values.

Our machines have given us more leisure than men have ever had before, and yet we apparently have never had less real leisure. Somewhere we have slipped. The machines that have given us free time enable us—almost force us by suggestions, pressures and abnormal mental or physical states—to misuse it. Instead of becoming gods, as science anticipated when it developed these machines and this control, we are becoming slaves.

The research spirit, with the use of historical fact, demonstrates that the dominance of material pursuits eventually devitalizes a society, brutalizes the people and leads to cultural and spiritual death. We have to keep our balance, establish criteria and get back to fundamentals. The spirit of research alone will enable us to distinguish the abiding, the socially and culturally sound from the opulent, the standardized, advertised and futile.

Not only do we live among standardized things, but our minds are subjected to standardized stimuli from radio hookups, newspapers and movies. In addition we have huge national and international organizations such as Kiwanis, Rotary, Lions and Optimists that give us far-reaching, standardized interpretations for the middle classes. We are standardized in our selling, buying and consuming, in our vices and virtues, or joys and sorrows, in leisure and working, politics and religion. We are becoming chain-store articles in almost every respect. What is worse, these standardizing agencies develop in us common feelings, prejudices and fetishes, and then, operating simultaneously among us as they do in our present state of concentrated populations, frequent distractions and lack of privacy and quiet, very easily produce crowd-mindedness among us. We are in danger of becoming marionettes with the strings pulled by syndicating journal-

ists, advertisers, professional uplifters, political spellbinders, evangelists or any one else who can gain the questionable reputation of being an "authority" or the leader of the temporary cult of "the thing." And, of course, as never before, the spinners of intellectual spider webs have their way and work their will upon us.

Especially sinister, in view of the situation just depicted, is the appalling apathy of a large number of our American youth, as well as many older people, in the realm of ideas and ideals. They want to avoid being thought of as "highbrow." They do not seem to be greatly interested in social or public questions, social reform or progress. So many of them swallow or at least accept what is taught them or what comes to them through all these other agencies with despair-provoking readiness. They are willing, nay eager, to conform to a type in the making of which they have done nothing. Many of them actually seem to approve of intellectual mediocrity, credulity and slavish acceptance, and avoid criticizing or holding opinions.

On the other hand, paradoxical as it may seem, the charge that our young people are in revolt can also be sustained. The younger generation in many cases are thoroughgoing critics of almost all conduct codes, customs, conventions and many of our social institutions. Most of these they look upon as time-worn and largely worthless encystments. They take joy in seeing idols smashed and eagerly participate in the process. Above all they want to avoid any appearance of softness or sentimentality in themselves. They want freedom from restraints imposed by earlier generations; they feel the urge to try themselves out in new social situations and strange environments; they yearn to taste the full flavor of their own freely expressed personalities. Along various lines they want a world of less protection and security, more adventure, more spontaneity, and they do most certainly go their own independent way in getting it.

V

Similarly as a reaction to the long-suppressed disgust with the fool's paradise of the war when everything was propagandized, and unpleasant or ugly facts were either ignored, denied or "dressed-up," we have had and are still having an epidemic of "realism" and "debunking." Some of our institutions, especially marriage and the church, are being challenged; the bourgeoisie have been classified and described in detail; business and advertising, Main Street and Park Avenue are being debunked; in fact, there are few sacred precincts. History has been divested of most of its misguided patriotic twaddle, and many of our great historical personages have been demonstrated to have had so much that was weak, petty and unscrupulous in their characters that, suspended between the old interpretation and the new, we are not sure whether our so-called great were saints or devils. Much of this dispelling of untruth and illusion is necessary, but there are objectionable extremes that must be considered. The sex novels, the "tough" plays, risqué movies and "true story" literature, under the guise of realism and with the aid of abnormal psychologies, have given us unbridled license, and a sickening parade of the pathological, the bizarre, the shocking and the unbalanced.

Real realism is most necessary. One can conceive of nothing worse than a world of well-varnished untruths and sticky sentimentalities inhabited by Pollyannas. Most of us take great joy in the exposure of some wilful misconception or sanctified absurdity. Moreover, a prudish passing by of a bad mess is both cowardly and silly. The veil needs to be lifted, secret evils should be acknowledged and the unlovely realities of

life faced. But instead of a crusade to expose sham our "realism" in so many cases has become "the cult of the seamy side." An honest, sincere, realistic facing of social facts also points to the normal, the wholesome, the sound—even the hopes, the ideals and the spiritual aspects of life—as being equally valid parts of the true picture. Why make life and sewers synonymous? It is essential to see this distinction between realism and the cult of the malodorous and abnormal.

Now no one wants to go back to the musty artificial confines of the Victorian world. At the same time one can not be in a perpetual quagmire of uncertainty or skepticism. Here the research spirit has a peculiar appeal as a dominant intellectual principle. It is realistic in the true sense of the word, for it points to certain inescapable laws and ultimate values that even a lawless and skeptical age learns that it must respect.

VI

Sinister also is the vast stock of nostrums and cure-alls which are offered us for every ill, personal or social, real or imaginary. These are similar to the All-healing Snake Oil ballyhooed by itinerant medicine venders from the back seats of surreys in Ohio towns when the writer was a boy. This great "nature's remedy" would cure everything from bunions to cancer. To-day religious ills may be promptly cured by any one of a dozen new cults. Amends may be made for our neglected health if we confine ourselves to foods with a given vitamin or take some other highly recommended pabulum. There are a dozen near-psychologies that will extricate us from a variety of troublesome neuroses and naughty complexes. A whole collection of panaceas is continually available to solve our social, political and economic problems, especially the major ones, such as crime, poverty and war. For the ills of nations we have offered sovietism, communism, fascism. Our forgetfulness can be corrected by a half dozen different memory courses, which, if carefully followed, will enable us to remember the names, addresses, telephone numbers, occupations, businesses, church memberships, lodges and luncheon clubs of ten thousand people (Selah). We are likely to grow as wise as Solomon or as cultured as Aristotle by purchasing two dollars' worth of pamphletized books or the famous five-foot shelf. (How the good Dr. Eliot would turn in his grave and groan if he knew what a cure-all had been made of his collection!) Some of these have a modicum of truth about them; others are patent inanities and insanities against which all should be insulated. Needless to say, intelligent people need to make their way among them and be able to evaluate them. Here again the research spirit is an ever-present and indispensable help.

VII

The changes in science itself, and the uses as well as the misuses of science, necessitate the research spirit if the citizen is to evaluate these changes properly and make the requisite adaptations. Our students, in the future, either as scientists or intelligent laymen, must be ever open-minded, flexible and eager for the best truth and the best new conclusions. The revolutions in thought precipitated by science, such as those connected with the names of Copernicus, Galileo, Newton, Harvey and Darwin, have just begun. We must be prepared to meet new facts in every field of scientific endeavor.

Furthermore, science is becoming so specialized and the amount of scientific knowledge so vast that the average citizen can not possibly know it all nor can he always utilize what he does know in his own life. Therefore each of us must become his own general scientist to some

extent. This is unthinkable without the research spirit.

Certain precautions must be observed in the utilization of science that can only be dictated by the research spirit. The second-rate scientists, and especially the popularizers, promise anything, and lead large numbers of people, now easily conditioned to any reputed scientific findings, to accept almost everything uncritically. Thus mere scientific assumptions become dogma for many, and a new bigotry appears comparable to any other in its power of resistance to truth. Men still need to think.

Science gives us prodigious power. How it is used depends upon the standards and perspective of the individual and the traditions and ideals of the group. The same scientific training equips men for the discovery of an anesthetic as of some poison gas, the production of the most deadly explosives as of the most effective soil fertilizers. The radio is an instrument that may confound and exploit us, or it may give us the sublimest creations of man and ennoble us. There is much truth in Thoreau's statement, "Our inventions are improved means to an unimproved end." We are, from many points of view, acquiring control of stupendous forces faster than we are developing the abilities to control ourselves. We are threatened with barbarism. Science can destroy our civilization; on the other hand, it is capable of converting the world into Utopia. Never before have men generally so needed real scientific background, mental poise, social perspective, moral balance and courage and the ability to evaluate and foresee. Never before have they so needed the research spirit.

Many of these college youth will enter professions or specialized technical callings. These too are changing continually. Research in chemistry, physiology, bacteriology and surgery is causing medical science to be in process of continual change, and the successful doctor must be able to incorporate these new findings and techniques into his own practice if he is properly to fulfil his function. The discovery of new materials, new data and new processes is forcing architecture and engineering to change. New methods and techniques and changing subject-matter are forcing the members of the teaching profession to refurnish themselves everlastingly. The changes in religion and the changing conception of the function of the church are forcing the clergy to readapt themselves. Every department of industry and business is changing in various ways. The individual member of the profession or calling must be alert, flexible in his attitudes, eager for the new truth and method, and he must have the inventiveness and ingenuity to put it into practice.

VIII

Finally there is great confusion to-day regarding the rightness and wrongness of individual acts. The present college generation especially has a difficult problem on its hands. It is seeking system and validity for its conduct. The reasons for the confusion are numerous. There is so much dishonest but temporarily successful behavior. So many of the "best" people are hypocrites; so much business is exploitation; so many statesmen vote dry and drink wet; so much patriotism turns out to be a distortion, and the sacred rights of property are invariably placed before the sacred rights of man. It is no wonder that the prevailing ethical maxim should be, "It's all right if you can get away with it."

At the same time science has taken away the supernatural bases of our morality. It demonstrates, for example, that any given ethical code is only one of a number practiced and maintained with equal success, and that two given

codes may be diametrically opposed in important aspects. Public opinion, another element in giving ethical codes fixity and sanction, has almost disappeared as far as private behavior is concerned. When it does operate it is weak and confused.

Finally, the social situations over which ethics presides as regulator are changing continually and along fundamental lines. Old rules become inadequate and ethical elements must continually be scrapped lest they become an incubus.

And yet we do have to live together and we must have order. Both present and future generations must make a most rapid, far-reaching and consciously intelligent orientation of ethical ideas to a continually altering social structure. We must be willing to make a careful examination of facts and requirements with respect to social relationships. We need the knowledge, imagination and logic to see and foresee social effects. We must be sane and calm and refuse to come to any but justifiable conclusions. We *must* have the research spirit.

IDEAS OF ORIGIN AMONG THE ANCIENT EGYPTIANS AND BABYLONIANS

By GEORGE J. DUDYCHA
RIPON COLLEGE

It has almost become traditional, when dealing with any phase of thought, to begin with a consideration of Greek ideas. The history of psychology begins with Plato; biologists refer to Aristotle, and sociologists to Plato's "Republic"; the history of Western philosophy almost invariably begins with Thales. Although we may readily admit that the Greeks are our progenitors in thought—our philosophical forefathers—we too often fail to recognize the thought which antedated that of the Greeks. We turn to Thales as though he were the Adam of all thought and neglect the equally profound ideas of the more ancient peoples of Egypt, India, China and Babylonia.

Osborn,[1] Fasten,[2] the present writer[3] and others all have begun with the Greek, Thales, in their accounts of the history of the idea of development. Perhaps this has led to the misconception that we are unable to trace ideas of origin any farther back than the sixth century B.C., and that the Greeks were the first to speculate concerning the beginning of things. If the thoughtful reader will reflect a moment, he will probably realize that our customary starting-point—Greek thought—is more convenient than logical, and hence he will be anxious to inquire concerning the ideas found in more ancient sources. Although the Greeks made contributions to philosophy of inestimable value, we do not know to what extent their ideas were influenced by those of more ancient peoples. Hence let us take another step into the remote past, beyond the thought of the Greeks, and see what ideas of origin we can find among the ancient Egyptians and Babylonians.

When we turn to the ancient sources of the Egyptian and Babylonian ideas concerning the origin of things we encounter many difficulties. In the first place, the ideas can not be ascribed to particular thinkers, as in the case of the

[1] Osborn, "From the Greeks to Darwin," Scribners, New York, 1929.

[2] Fasten, "Origin through Evolution," Knopf, New York, 1929.

[3] Dudycha, "What is Evolution?" SCIENTIFIC MONTHLY, 29: 317–332, October, 1929.

Greeks, for the tablets and papyri are in many cases unsigned, and if they are signed, the signature is not that of the author of the ideas but of the copyist or of the priest who authorized the copying. Also the sources are for the most part fragmentary and thus complete accounts of the ideas of origin are impossible. Since the texts available to scholars are in many cases corrupt because of the numerous times they have been copied by careless scribes, it is extremely difficult to interpret certain passages and to ascertain the original ideas. Some of the ancient legends date back to the second, third and possibly fourth millennium B.C. Since they had been perpetuated orally through innumerable generations before being recorded, they were developed into a number of versions, which makes interpretation very difficult. In some cases the scribes themselves did not understand the texts which they copied and hence modified them to suit their own fancies by omitting some ideas, by adding others or by combining a number of legends or fragments of legends to form a more or less incoherent story. Fortunately, in spite of these difficulties, tablets and papyri have been unearthed which bear well-preserved records of ancient ideas of origin which apparently date back to the early dynasties of Egypt and to the ancient Sumerians who preceded the Semites in Babylonia. It is to these primeval records that we shall now turn for a knowledge of the early Egyptian and Babylonian ideas of origin.

In the British Museum may be found the remarkable "Legend of the Creation," a well-written papyrus acquired by A. H. Rhind in 1861 or 1862. This papyrus, which was discovered in the famous hiding-place of the royal mummies at Dêr-al-Bahari, bears the date, the "first day of the fourth month of the twelfth year of Pharoah Alexander, the son of Alexander," or 311 B.C. We must bear in mind, however, that this Nes-Menu papyrus is not the first account of the legend but a copy, and that scholars feel quite certain that the legend itself dates back to several millennia B.C. Thus the discovery of this papyrus was a particularly fortunate one, for we now have a source which bears ideas of origin which antedate those of the Greeks. Dr. Budge in his first volume of "Egyptian Literature"[4] gives us the legend of the creation in hieroglyphic type and also a page-for-page translation. This Nes-Menu papyrus bears two accounts of the creation which are alike except for some details and for a few additions to the second account which were apparently made by the copyist. The first account of the history of creation is as follows:

THE BOOK OF KNOWING THE EVOLUTIONS OF RA, AND OF OVERTHROWING APEP

[These are] the words which the god Neb-er-tcher spake after he had come into being: "I am he who came into being in the form of the god Khepera, and I am the creator of that which came into being, that is to say, I am the creator of everything which came into being; now the things which I created, and which came forth out of my mouth after that I had come into being myself were exceedingly many. The sky [or heaven] had not come into being, the earth did not exist, and the children of the earth and the creeping things had not been made at that time. I myself raised them up from out of Nu, from a state of helpless inertness. I found no place whereon I could stand. I worked a charm upon my own heart [or will], I laid the foundation [of things] by Maāt, and I made everything which had form. I was [then] one by myself, for I had not emitted from myself the god Shu, and I had not spit out from myself the goddess Tefnut; and there existed no other who could work with me. I laid the foundations [of things] in my own heart, and there came into being multitudes of created things, which came into being from the created things which were born from the created things which arose from what they brought forth. I had union with my closed hand, and

[4] Budge, "Egyptian Literature," Vol. I. "Legends of the Gods," London: Kegan Paul, Trench, Trubner and Co. Ltd., 1912.

I embraced my shadow as a wife, and I poured seed into my own mouth, and I sent forth from myself issue in the form of the gods Shu and Tefnut. Saith my father Nu: My Eye was covered up behind them [*i.e.*, Shu and Tefnut], but after two *hen* periods had passed from the time when they departed from me, from being one god I became three gods, and I came into being in the earth. Then Shu and Tefnut rejoiced from out of the inert watery mass wherein they were, and they brought to me my Eye [*i.e.*, the Sun]. Now after these things I gathered together my members, and I wept over them, and men and women sprang into being from the tears which came forth from my Eye. And when my Eye came to me, and found that I had made another [Eye] in place where it was [*i.e.*, the Moon], it was wroth with [or raged at] me, whereupon I endowed it [*i.e.*, the second Eye] with [some of] the splendor which I had made for the first [Eye], and I made it to occupy its place in my Face, and henceforth it ruled throughout all this earth. When there fell on them their moment through plant-like clouds, I restored what had been taken away from them, and I appeared from out of the plant-like clouds. I created creeping things of every kind, and every thing which came into being from them. Shu and Tefnut brought forth [Seb and] Nut; and Seb and Nut brought forth Osiris and Heru-khent-an-maati and Set and Isis and Nephthys at one birth, one after the other, and they produced their multitudinous offspring in this earth."[5]

We are not told in this account of the creation where and how Neb-er-tcher came into being; but, as Budge says, "It seems as if he was believed to have been an almighty and invisible power which filled all space." This immediately suggests Anaximander's idea of "the boundless" as the source of all things. Although the Egyptians labeled this source-of-all-things and called it a god, their fundamental idea, that there is an indefinable boundless something from which all things issue, is certainly much like that of Anaximander. Another idea which we find expressed here and which was emphasized by the early Greeks is that of the unity of the primal principle. Neb-er-tcher, who took on the form of Khepera, the creator god of the Egyptians, was the sole primal source of all creation.

The next significant idea we find embodied in the statement, "I myself raised them up from out of Nu, from a state of helpless inertness." Nu, sometimes referred to as Nun, was the great watery abyss, the primal watery mass which was the source and origin of all things organic and inorganic. "The most wide-spread of all," says Steindorff, "was a belief which perhaps proceeded from the priestly college of Heliopolis. According to this there was in the beginning a great primordial body of water called Nun, which contained all male and female germs of life. Out of it came the sun, the Rē, as it is called in Egyptian. In this water, too, lay the earth-god Geb and the heavenly goddess, Nut, locked in a close embrace, until the god of the air, Show, parted them from one another and carried the goddess of heaven in his arms into the upper regions."[6] This concept of Nu, the great abyss, symbolized by the ocean, a representative of which was the gentle Nile, is a most interesting concept which contains two fundamental ideas. First the idea of water as the primeval substance. This idea we encounter among the Greeks. Thales, the Ionian, named water as that from which all things come, and Aristotle iterated the idea with reference to all life. Also we note that in Nu all things were in "a state of helpless inertness" from which they were freed by becoming actual. Of course, we must beware of too free speculation concerning the ideas of the ancient Egyptians, but we can not avoid a reference to Augustine in this connection. For Augustine all things were potential in an original germ or seed from which all things came. It is this potentiality of forms in the primordial

[5] Budge, "Legends of the Gods," Vol. I, pp. 3–7.

[6] Steindorff, "The Religion of the Ancient Egyptians," p. 36, G. P. Putnam's Sons, New York, 1905.

mass which seems to be common to both concepts.

In a cosmogonic fragment from the "Book of the Dead," we find another reference to Nu.

Furthermore I shall ruin all that I have made.
This earth will appear [?] as an abyss,
In [or as] a flood as in its primeval condition.
I am the one remaining from it together with Osiris.
My forming is [then] made to me among other [?] serpents
Which men never knew,
Which the gods never saw.[7]

Here another aspect of Nu is emphasized. Not only is Nu the source of all things, but the end as well—that from which all things come and that to which all things return. Here, again, is Anaximander's idea.

Again we read in our text, "I laid the foundation [of things] by Maāt." The goddess Maāt, who assisted Khepera in the process of creation, is usually regarded as the goddess of law, order and truth. Budge is inclined to believe that in this particular instance she plays the part of Wisdom. Thus, in the thought of the Egyptians, we again find a concept which has been fundamental to all concepts of origin and development, namely, the concept of law and order.

The first products of creation, the legend tells us, were Shu, the god of air and dryness; Tefnut, the goddess of liquids or the waters above the heavens; Keb, the earth-god, and Nut, the sky-goddess. Thus first air and clouds appeared which separated the heavens from the earth. Later the legend speaks of Neb-er-tcher's or Khepera's eye or the sun as having some calamity which extinguished its light. "This calamity," Budge says, "may have been simply the coming of night, or eclipses, or storms; but in any case the god made a second Eye, *i.e.*, the Moon, to which he gave some of the splendour of the other Eye, *i.e.*, the Sun, and he gave it a place in his face, and henceforth it ruled throughout the earth, and had special powers in respect of the production of trees, plants, vegetables, herbs, etc."[8] The latter part of the legend is somewhat confusing, especially with regard to the creation of man, with which we shall deal presently.

In the Trismegistic "Tractates" the tradition and wisdom of ancient Egypt has come down to us in a slightly modified Alexandrian form. Although this source has been assigned to the fifth or possibly sixth century B.C., the ideas "go back in an unbroken tradition of type and form and context to the earliest Ptolemaic times." Most of this Hermetic or Trismegistic literature has been destroyed, but among that which has not perished we find "The Vision of Hermes,"[9] under the name of Poimandres, which is in the beginning of the books of Hermes Trismegistus. "The Vision of Hermes" is the revelation of the origin of things by Osiris who in later Egyptian thought became associated with Nu, the primal mass. Hermes' first request of Osiris was "to behold the source of beings." Immediately he found himself in a chaos filled with smoke. Then a voice, *the cry of light*, rose from the great abyss and a flame darted to the ethereal heights. Hermes ascended with the flame and observed order appear, and that *the voice of light* filled infinity. Hermes did not understand the meaning of all he saw and hence Osiris explains:

Thou wilt now learn. Thou hast just seen what exists from all eternity. The light thou didst first see is the divine intelligence *which contains all things in potentiality*,[10] enclosing the models of all beings. The darkness in

[7] Gray (Editor), "The Mythology of all Races," Vol. XII, Muller, "Egyptian," p. 72, Marshall Jones Company, Boston, 1918.

[8] Budge, *loc. cit.*, p. xxi.

[9] Hermes was the name given by the Greeks to the Egyptian god Thoth or Tehuti, the god of wisdom, learning and literature.

[10] Italics are mine.

which thou afterwards plunged is the material world on which the men of earth live. But the fire thou didst behold shooting forth from the depths, is the divine Word.[11]

But Hermes desired more knowledge. "Since things are so," said Hermes, "grant that I may see the light of the world; the path of souls from which man comes and to which he returns." Thus Hermes found himself in the center of the seven spheres which stretched above him, tier upon tier, like seven transparent concentric globes. Again the great Osiris speaks:

"Look, listen, and understand. Thou seest the seven spheres of all life. Through them is accomplished the fall and ascent of souls. The seven genii are the seven rays of the world-light. Each of them commands one sphere of the spirit, one phase of the life of souls. . . .

"Dost thou see," said Osiris, "a luminous seed fall from the regions of the milky way into the seventh sphere? These are germs of souls. They live like faint vapors in the region of Saturn, gay and free from care, knowing not their own happiness. On falling from sphere to sphere, however, they put on increasingly heavier envelopes. In each incarnation they acquire a new corporeal sense, in harmony with the surroundings in which they are living. Their vital energy increases, but in proportion as they enter into denser bodies they lose the memory of their celestial origin. Thus is effected the fall of souls which come from the divine ether. Ever more and more captivated by matter and intoxicated by life, they fling themselves like a rain of fire, with quiverings of voluptuous delight, through the regions of grief, love, and death, right into their earthly prison where thou thyself lamentest, held down by the fiery center of the earth, and an empty dream. . . . Do you see this swarm of souls trying to mount once more to the lunar regions? Some are beaten back to earth like eddies of birds beneath the might of the tempest. The rest with mighty wings reach the upper sphere, which draws them with it as it rotates. Once they have come to this sphere, they recover their vision of divine things. This time, however, they are not content to reflect them in the dream of a powerless happiness; they become impregnated thereby with the lucidity of a grief-enlightened consciousness, the energy of a will acquired through struggle and strife. They become luminous, for they possess the divine in themselves and radiate it in their acts."[12]

In "The Vision of Hermes" there are at least two thoughts which we must note, first, the potentiality of all things in divine intelligence, and second, the descent of the souls through seven stages. Here we note, then, an evolutionary—unfolding—process, and an epigenetic—building-up—process. The two processes, however, are not incompatible, for the souls, although passing through an epigenetic process towards materiality, are the unfoldment of that which is in divine intelligence. "One only soul, the great soul of the All, by dividing itself out, has given birth to all the souls that struggle throughout the universe." Thus, here again, we have the ideas of unity of origin and process of development expressed.

The descent of the souls, told in "The Vision of Hermes," is one account of the creation of man. In the "Legend of the Creation" we found two other and somewhat incompatible ideas of the origin of man. The first was that Neb-er-tcher wept, "and men and women sprang into being from the tears which came forth from my eye." In the other version, the gods gave birth and "produced their multitudinous offspring in this earth." According to the second notion, men are mortal gods. This lack of harmony which we find with regard to the origin of man is probably due to the fact that these conflicting legends appealed to the scribes who desired to perpetuate them in spite of their lack of unity. Then again, it has been observed that the very lack of unity in the "Legend of the Creation" made it a more potent charm against Apep and his fiends.

Now that we have an idea of the Egyptian notions of origin, let us turn

[11] Brown, "The Wisdom of the Egyptians," p. 264, Brentano's, New York, 1923.

[12] Brown, *loc. cit.*, pp. 266, 267–8, 269.

to the ancient Sumerians and the Semitic Babylonians who succeeded them. At Nippur, tablets, inscribed at the close of the third millennium B.C., have been found which bear Sumerian and Semitic accounts of creation. Although the available text was inscribed before 2100 B.C., the original composition dates back to a much earlier time, and thus we are again able to examine ancient ideas of origin.

It is interesting to note that the ancient Sumerians, as the Egyptians, Hebrews and Greeks, assumed that water is the source of all things. King renders a fragment of a poem which deals with creation as follows:

When the height heaven was not named,
And the earth beneath did not bear a name,
And the primaeval Apsû who begat them,[13]
And Mummu, and Tiamat who bore them[13] all—
Their waters were mingled together,
. . . .
Then were created the gods in the midst of [their waters],
Lakhmu and Lakhamu were called into being. . . .[14]

He goes on to say that the text gives two actual causes of creation, the one an impersonal cause and the other the action of a god. In the following extract we note that before creation all the world was a sea. Here, however, the primeval water is not personified and hence the impersonal source of all things.

No city had been created, no creature had been made,
Nippur had not been created, Ekur had not been built,
Erech had not been created, Eanna had not been built,
Apsû had not been created, Eridu had not been built,
Of the holy house, the house of the gods, the habitation had not been created.
All lands were sea.

[13] *I.e.*, the gods.

[14] King, "Legends of Babylon and Egypt in Relation to Hebrew Tradition," p. 122, London, 1918.

At the time when a channel [was formed] in the midst of the sea,
Then was Eridu created, Esagila was built, etc.[15]

A different picture of beginnings is given in another Sumerian myth which was discovered on a tablet from Nippur. Although in this myth water is considered as the source of all life, the existence of land is presupposed—land which is bare and desolate. King says: "The underlying idea is suggestive of a period when some progress in systematic irrigation had already been made, and the filling of the dry canals and subsequent irrigation of the parched ground by the rising flood of Enki was not dreaded but eagerly desired."[16] Here we have an analogy. As water revives vegetation, so water must have been essential or the cause of the first appearance of life.

As the Egyptians regarded the Nile as a representative of Nu, so the Babylonians attributed creative powers to the Euphrates. This is indicated by the following lines from a Semitic incantation:

O thou River, who didst create all things,
When the great gods dug thee out,
They set prosperity upon thy banks.
Within thee Ea, King of the Deep, created his dwelling.
The Flood they sent not before thou wert![17]

Yet another idea is to be noted in the Semitic-Babylonian version of the creation of the world. Creation for the Semites was the result of a conflict in which order emerged out of chaos because of the personal triumph of the creator. This dualism does not seem to be present in the more primitive Sumerian ideas. This idea of conflict we have encountered before. Empedocles posited two world forces, love and hate, which were in conflict, and the triumph of love over hate was the cause of organic evolution.

[15] King, *loc. cit.*, p. 124.

[16] King, *loc. cit.*, p. 125.

[17] King, *loc. cit.*, p. 128.

Since we have examined in detail the ideas of origin found among the ancient Egyptians and Babylonians, let us now briefly survey the main ideas which we found. Although the references to the creation are by no means numerous in Egyptian literature, because the Egyptians' interest, which almost amounted to an obsession, was in a future life rather than in the past, we fortunately have the invaluable Nes-Menu papyrus—the "Legend of the Creation." In spite of the fact that this ancient legend was appropriated to Egyptian theology by the priests, we have found in it fundamental ideas which are common to other cosmogonic views. Especially did we note striking likenesses to Greek thought.

Neb-er-tcher, the invisible power which filled all space and which was the primal source of all creation, suggests at once "the boundless" of Anaximander and the monisms urged by a whole host of thinkers. Nu, the great watery abyss, again suggests the Greeks who early perceived how indispensable is water to life. But Nu has a further significance: in it all things are potential and to it all things return. These ideas were expressed by Augustine and by Anaximander. As in Western thought, law and order played a part in the Egyptian idea of creation. In "The Vision of Hermes," we noted a number of significant ideas: the cry of light was symbolized as a flame—the primacy of fire; the potentiality of all things in divine intelligence; the definite epigenetic process through which the souls pass on their way towards materiality.

When we turned to the Sumites and Semites we found that they too recognized water as the primal source of all creation. In the Sumite cosmogonic idea, the sea is an impersonal force not personified as by the Egyptians. The idea of conflict and subsequent triumph of the creator, which reminds us of Empedocles, is an idea not found among the Sumerians but apparently originated by the Semitic-Babylonians.

Thus in closing we must reiterate. The Greeks were not the first to speculate concerning the origin of things, for we find among the Egyptians and Babylonians cosmogonic ideas of far more ancient origin, which, when divested of their theological implications and deity names, are not so far different in nature and significance from those of more recent and of Western thought.

SCIENCE SERVICE RADIO TALKS

PRESENTED OVER THE COLUMBIA BROADCASTING SYSTEM

COLD LIGHT

By Dr. E. NEWTON HARVEY

PROFESSOR OF PHYSIOLOGY, PRINCETON UNIVERSITY

THE words "cold light" seem at first sight to state a paradox. So closely associated are light and heat in all our experience that the two would seem inseparable. The sun is not only the brightest but also the hottest object in our immediate neighborhood.

Practically every illuminant in use to-day is patterned after the sun and stars. The attempt is made to heat an incandescent filament to the highest temperature possible. We can not attain the temperature of the sun, five or six thousand degrees, but we do attain two fifths the temperature of the sun and a brightness sufficient to convert our principal thoroughfares into great white ways. No artificial lamp is known but that gives off ample heat to be felt by the hand. It is all "hot light." The heat is not only a drawback; it is an actual waste, a waste so great that it represents about 98 per cent. of the total energy. We use a 50 horse-power engine to run the dynamo that lights a few bulbs, when 1 horse-power might do the same thing if we knew the secret of the process. Modern incandescent bulbs are already many times more efficient than those first constructed, but we are apparently approaching the limit. How can we improve the efficiency of our light-producing processes still further? I think we must turn to a type of light which, as we say, radiates very selectively, *i.e.*, it gives off mostly radiant wave-lengths which affect our eye and very few of those which have great heating power but which are invisible. Such lights we speak of as cold lights or luminescences, and contrast them with hot lights or incandescences.

Luminescences are by no means unusual. They are in fact quite common. Two lumps of sugar rubbed together in a perfectly dark room will give off a faint light. We call it tribo-luminescence. Tire tape or surgeon's tape gives a greenish glow when stripped from the roll. Common salt can be made to luminesce when it crystallizes rapidly. These lights are very faint, and indeed that is characteristic of luminescence in general, but it is not always a serious drawback for practical purposes. The radium paint used on watch dials is a luminescence, a radio-luminescence, and yet has a very useful rôle to play. In fact the modern trend in lighting is that of indirect illumination. A very bright light is fatiguing, indeed obnoxious. We spread our bright light over a large area by shades or reflectors and thus avoid the glare, reducing what is called the "intrinsic brilliancy" of the light. Some luminescences are bright enough for practical illumination but the color is bad. I refer to neon lamps, so widely used as signs and in advertising. They are true luminescences and among the most efficient types of commercial lamps but they still leave a great deal to be desired as a general illuminant.

Perhaps the most promising field for study is that of chemi-luminescences, the luminescences which accompany chemical reactions. These appear dur-

ing chemical change, chiefly during oxidation, and can be studied in test-tubes. A number of organic compounds in water solution can be made to produce quite a bright light with only a few thousandths of a degree rise in temperature. This is the method of producing light adopted by the firefly and other luminous animals. The layman does not realize how many creatures have this power. Many of them live in the depths of the sea or under rocks and stones. Some microscopic forms develop under favorable conditions at the surface of the sea in enormous numbers, giving rise to the phosphorescence, so well known to ocean voyagers. Others develop in decaying wood, producing the fox-fire of forests. Even some bacteria are luminous, causing the glow of dead fish or meat in refrigerators.

All emit a light which is a luminescence, a bio-luminescence, and which results from the oxidation of a compound manufactured in their tissues and called luciferin. Its exact composition is not known but we have considerable knowledge about it, and I believe the synthesis of luciferin is merely a matter of time. Let us inquire somewhat more closely into the luminescence of this compound and the light of living things in general.

It should be clearly understood at the start that animal light—cold light—is no different in its physical make-up from any other kind of light. Animal light can be reflected and refracted and polarized, will affect a photographic plate, and is stopped by materials capable of stopping similar wave-lengths from any other source. Such a light would do perfectly well as a practical illuminant. The light of some luminous animals has an intrinsic brilliancy sufficiently high for general illumination. It has been calculated that an area of firefly light 6 feet in diameter on the ceiling of a room 9 feet high would give ample illumination for reading or drawing on a table 3 feet high.

Not all luminous animals are as bright as the firefly. Many produce only a diffuse glow from irregular areas or from the whole surface of the body, and some pour out a luminous substance leaving a trail of light behind them as they swim, while others have the light-producing cells concentrated into a definite organ. In some cases this light organ is provided with reflectors for directing and a lens for concentrating the beam, as well as opaque screens to protect the tissues of the animal from its own light and a mechanism for turning the light off and on. In a few forms are color screens for regulating the quality of the light. A veritable lantern is formed which we may suppose to be of some important use to its possessor.

What goes on in the cells of those animals which can produce light? They are the test-tubes of the living organism. I have said that a compound, luciferin, is oxidixed or burned, a process similar to that which takes place in a burning candle. This oxidation occurs in the presence of another compound, luciferase, an enzyme or catalyst. In this respect it differs from a burning candle. Now a catalyst is a substance which takes no permanent part in a chemical reaction, but by its mere presence causes the reaction to proceed. It has been called a "good mixer" or a "chemical parson," because it causes substances to become acquainted and unite. Its effect has been compared to that of oil on a rusty machine, and catalysts are becoming of more and more importance in the chemical industries.

During the oxidation of luciferin, the luciferase molecules pick up some of the energy of oxidation and are "excited," as we say, to emit light, when they return to their normal condition. They are then ready to repeat the cycle again.

All this happens in a time interval measured in fractions of a millionth of a second. The average of all the minute amounts of light emitted by all the luciferase molecules give us the firefly's light as it appears to our eye.

There still remains the question of what happens to the luciferin after it has been oxidized or burned. For many years those who thought at all about luminous animals supposed that the luciferin oxidized with formation of carbon dioxide and water, the same products as appear when a candle burns. This is not the case, and in this fact lies the secret of the small energy change occurring during its oxidation. Luciferin does not oxidize to CO_2 and H_2O, but to a substance I have called oxyluciferin.

The important point is that by simple methods oxyluciferin can be easily reduced to luciferin. Reduction is the opposite of oxidation. The reformed luciferin can be again oxidized with luminescence. Not only is the luciferase able to pick up energy from oxidizing luciferin again and again but the luciferin is capable of alternate oxidation and reduction in a continuous cycle. Why not allow the two processes to proceed side by side in the same vessel and obtain a continuous light? Reduce the luciferin as fast as it is oxidized, and use it over and over again.

This would be comparable to burning a candle, and then by some means recombining the oxidation products of the candle, the water and carbon dioxide, to tallow again. Our present way to reform a tallow candle is to let sunlight fall upon the leaves of the green plants, when CO_2 and H_2O will be recombined with absorption of the energy of sunlight, and starch, a compound rich in energy, will be built up. Then some animal must eat the starchy food and convert it into tallow, which is again in a position to be burned with liberation of energy, some of which goes into the light of the candle.

What is impossible in the case of the tallow is quite possible in the case of luciferin. By simultaneous reduction of oxyluciferin and oxidation of luciferin, a continuous light can be produced —not a very bright light, to be sure, but one which demonstrates the principle, and the principle is the important thing.

And what an economical process this is! Here you have an animal that makes its fuel and burns it and produces light, practically pure visible light, for it is not contaminated with those unbidden rays we can not see; and then it takes the combustion product and reconverts it into fuel again, and the fuel is ready to be burned a second time. The firefly is able to unburn its candle. And all this by a process which is in no sense a mystery. The chemist calls it a reversible reaction, and if you should ask him whether this is not a rather rare thing, he would probably reply: "All chemical reactions are reversible, but to a different degree."

The application of an old principle in a new way has solved many a problem. It is perhaps too soon to predict what may be the commercial future of cold light, but it is worthy of emphasis that such a development would be a very decided step in the right direction. We usually find that nature has selected efficient and economical ways of doing things and it is no wonder that the cold light of animals has been the goal of the illuminating engineer, ever since our advancing knowledge reached the point where appreciation of the principles of light-production was possible.

SUN-SPOTS AND RADIO

By Dr. H. T. STETSON
DIRECTOR OF THE PERKINS OBSERVATORY, OHIO WESLEYAN UNIVERSITY

SOME radio enthusiasts who have been long at the game may sense that of late years long distance reception has not been coming in as it did in the early days of broadcasting, five or six years ago. This is the more significant when we consider that the output of the broadcasting stations has been increased immensely and that great improvement has been made in receiving sets over this interval

Studies during the last few years indicate that there are cosmic causes at work which may profoundly influence the electrical state of our atmosphere which these radio waves traverse. Probably the sun is the one astronomical body most responsible for changes in our terrestrial affairs. Every radio fan knows that day-time reception is vastly poorer than night-time reception in the broadcasting zone. Here is the most obvious exhibition of the effect of the sun's rays upon radio. On the other hand, both day and night reception vary greatly from time to time for what has often seemed to be no good reason at all. It is from relatively very recent researches that we have come to believe much of the cause for this varying degree of reception is to be found in the sun's atmosphere itself.

When we examine the sun's surface through the telescope, we find that it presents a strange mottled or granular appearance. In this mottled surface there develop now and then dark patches, often growing into huge black areas surrounded by a somewhat shaded region called the penumbra. These dark areas are the sun-spots. Whatever may be ultimately accepted as the best explanation of the spots, one can not go far wrong in picturing a sun-spot as a terrific storm in the sun's atmosphere, a cyclonic whirlwind for which the most violent tropical hurricane would be a microscopic illustration.

One of the most extraordinary features of sun-spots is the periodicity with which they appear on the solar surface. For nearly a century and a half sufficiently accurate records of the appearance of sun-spots have been made, so that if we plot the degree of spottedness of the solar surface year by year, we discover a periodic rise and fall in the stormy condition of the sun's surface spanning approximately eleven years. We are now not far from what we call a sun-spot maximum. About six years ago sun-spots were very scarce and, when they occasionally appeared, were very small and insignificant affairs.

Curiously enough, at the beginning of a sun-spot cycle the spots appear on the sun's surface at relatively high latitudes, and as the cycle progresses they increase in size and number and break out at successively lower latitudes on the solar sphere, a given cycle of spots finally disappearing just a few degrees from the solar equator.

The true character of sun-spots as magnetic whirls in the solar atmosphere was first established by Hale, of the Mount Wilson Observatory, in 1908. By a special adaptation of the spectroscope, Hale was able to photograph different layers in the solar atmosphere and establish the existence of vortices similar to the whirlwinds which are characteristic of cyclonic storms in the earth's atmosphere. Furthermore, by analyzing the character of the rays of light radiating from the sun-spots, Hale was able to demonstrate that the character of the light emitted from the center of these

gigantic whirls betrayed unmistakably that they were the poles of powerful electromagnets, and that the doubling and tripling of lines in the spectrum in the vicinity of sun-spots was due to the magnetic effect announced by Zeeman in 1896.

The mention of sun-spots invariably raises the question of a possible connection between the spots on the sun and terrestrial phenomena. Some statisticians with an insatiable appetite for correlations have attempted to connect with sun-spots almost every cycle in world affairs from fluctuations in the New York stock market to the fecundity of rabbits in northern Canada. In the popular mind, almost every world catastrophe has sooner or later been attributed to sun-spots, from a Florida hurricane to the great world war, both of which, by the way, did culminate around a sun-spot maximum.

But seriously there are to the scientist certain well-recognized phenomena on the earth which pass through cycles whose correlation with the sun-spot cycle is unmistakable.

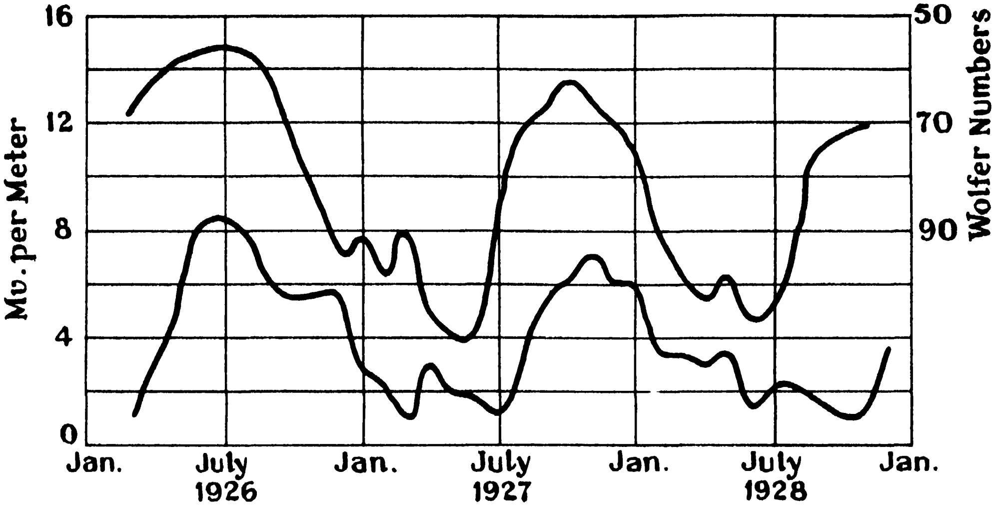
For more than a century and a half records of the numbers of sun-spots have been kept and afford data for a study of their periodicity over a range of about fifteen eleven-year cycles. For more than a century records of the variation in the earth's magnetism have been made and preserved. The remarkable correlation of sun-spots with magnetic changes on the earth is at once apparent when we make a graph of the number of sun-spots and compare this with a similar graph for changes of the compass needle. Simultaneously with the so-called magnetic storms, which are wont to sweep the earth upon the appearance of great sun-spot activity, we witness frequent and brilliant displays of the aurora borealis.

The auroral light is due to an electronic discharge in the upper and highly rarefied atmosphere of the earth, and is most probably activated by charged particles of electricity emanating from the sun whose activity varies with the sun-spot cycle. It seems probable that the magnetic vortical whirl of a sun-spot acts as a directing field in guiding electrons escaping from the sun. When a conspicuous spot appears near the center of the solar disk, and is therefore approximately in line with the earth and the sun's center, there is a particularly good chance of the ejected electrons striking the earth's atmosphere and causing an ionization or electrification of the upper atmosphere giving rise to an auroral display At the same time the induced earth currents will distort the earth's magnetic field, causing the small variations in the compass needle so characteristic of a "magnetic storm."

While for many generations scientists have recognized the recurrent cycle in solar activity and the magnetic changes in the earth, never before the present period of sun-spot activity has it been possible to study so thoroughly the changing degree of electrification in the earth's atmosphere with the coming and going of the spots across the solar disk. All this has come about by the development of the radio.

The same electric disturbances which alter the earth's magnetic field and produce the displays of the aurorae or northern lights so change the electrical state of our atmosphere that the radio waves are also affected to a very marked degree by the coming and going of the gigantic solar cyclones.

I have before me a graph showing the number of sun-spots during the twelve months of the year 1926, and alongside another graph showing the average condition of radio reception over the North Atlantic, South Atlantic and across the continent. The sun-spot graph is made from the so-called Wolfer numbers. These numbers are based upon the number of spots visible on the sun's surface at a given time and to some extent upon



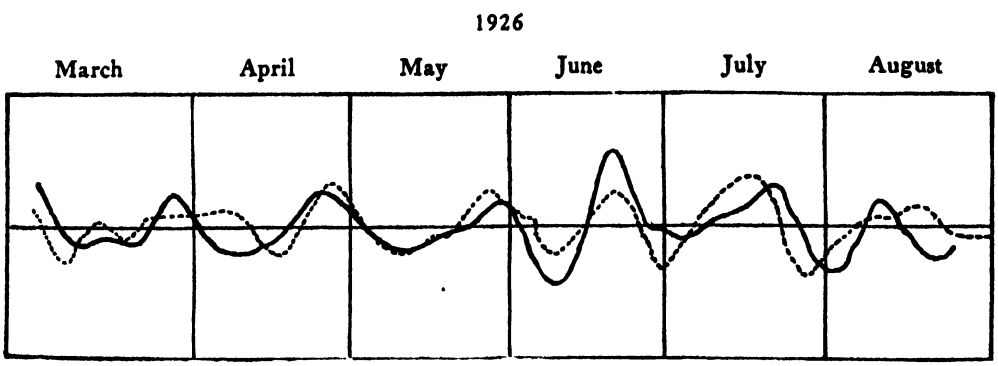
UPPER CURVE SHOWS INVERTED SUN-SPOT NUMBERS. LOWER CURVE RADIO INTENSITY MEASUREMENTS.

their area, but do not take into account the position of the spot on the sun's disk. The general run of these graphs indicates that radio reception is distinctly impaired by an increase in the sun-spot numbers.

Quantitative measurements of radio reception since 1926 seem to have established beyond much doubt that long distance night reception in the broadcast zone is in general poor when sun-spots are numerous and good when the spots are few. The quantitative measurement of radio reception in the broadcast zone was begun by Mr. G. W. Pickard in his private laboratory at Newton Center in February, 1926, and great credit is due him for his pioneer work and his preeminent contributions in this field.

If we plot a graph of the inverted curve of sun-spot numbers for the years 1926 to 1929, and another graph alongside showing the varying intensity in the carrier wave from WBBM in Chicago as received in Boston and based on the results of measurements by Pickard and Stetson, the inverse correspondence between radio intensities and sun-spot numbers becomes readily apparent.

Every night, Sundays and holidays included, three stations, one in Massachusetts, one in Ohio and one in Cali-



CURVE SHOWING CORRELATION OF SUN-SPOTS WITH RADIO RECEPTION

DOTTED CURVE, THE INVERSE OF SUN-SPOT NUMBERS; FULL CURVE, RELATIVE INTENSITY OF RADIO RECEPTION ON TRANSATLANTIC, SOUTH AMERICAN AND CONTINENTAL RECEPTION

fornia, tune in on a prescribed wave-length to study the effect of the day's solar radiation upon the electrical state of the earth's atmosphere. Not trusting to any personal impressions as to whether reception is excellent, good, fair or poor. an attendant closes the key to the automatic recorder, whose faithful pen with an impersonal but almost uncanny intelligence writes a continuous record of the intensity of the incoming waves. It is with utter disregard for astronomical or electrical theories that it leaves its unprejudiced and indelible record of what happens for the scientist to analyze.

In addition to the measurement of radio reception the sun is photographed at the Perkins Observatory every clear day in cooperation with the Yerkes, Mount Wilson, Harvard and Naval Observatories, and a careful study made of the size, numbers and location of the sun-spots. It is believed from a preliminary study that the distance of the spots from the center of the disk, or the sun-earth line, is an important factor in the study of correlation of sun-spots with radio reception and other electromagnetic phenomena on the earth.

The radio apparatus recently installed and now in daily operation at the Perkins Observatory is a super-heterodyne receiver especially constructed for the purpose and feeding into a self-recording galvanometer which registers in micro-volts in the antenna the strength of the carrier wave received from the broadcasting station of WBBM Chicago. The apparatus is so designed that the modulations of the carrier wave do not affect the record appreciably, and the results obtained are independent of the nature of the program broadcasted. Realizing the importance of the investigation, the broadcasting station scrupulously maintains a constant energy output in its antenna current, and each night before the observers begin work the receiving set is carefully calibrated by means of a small sending station in the laboratory placed in close proximity to the receiving set. The output of the local oscillator necessary to maintain full deflection upon the recorder in the receiving circuit is then read from the microammeter in the circuit. The constant of the apparatus for the evening is thus determined. In this way local sources of error both at the broadcasting and receiving ends are eliminated and the resulting measures of the variable reception from night to night may be attributed to the changing electrical conditions of the atmosphere through which the broadcasted wave travels *en route* from Chicago to the receiving station.

Opinions differ as to just what happens when a broadcasted wave travels over the earth Some believe that an ether wave is propagated which is reflected back to earth from an ionized layer of the earth's atmosphere known as the Kennelly-Heaviside layer which lies some seventy kilometers above the earth's surface. Others maintain that the electric wave is refracted rather than reflected from such a layer. Whatever the mechanism, the wave appears to be turned back by this ionized layer of the earth's atmosphere. Any change in the intensity or degree of this ionization or electrification of the earth's upper atmosphere would have the effect of bending the ray more abruptly or less abruptly towards the earth and thereupon at once be noticed in the intensity of radio reception. The more rapid changes of this sort are doubtless responsible for the phenomena of fading, with which every radio fan is thoroughly familiar. According to our theory the sun constantly bombards the earth's atmosphere with electrons or bundles of energy of high frequency which in turn tear apart the positive and negative charges of the atmospheric molecules, in other words, ionize it to a very consid-

erable extent, thus producing the Kennelly-Heaviside layer. If the sun is more active on occasion, as when large spots appear on its surface, the degree of ionization increases, producing substantially the effect of lowering the Kennelly-Heaviside layer and upsetting the radio reception. When the sun is again less active, the atmosphere tends to return to its normal state of ionization and the radio broadcasting reception tends to improve as the ionized layer lifts.

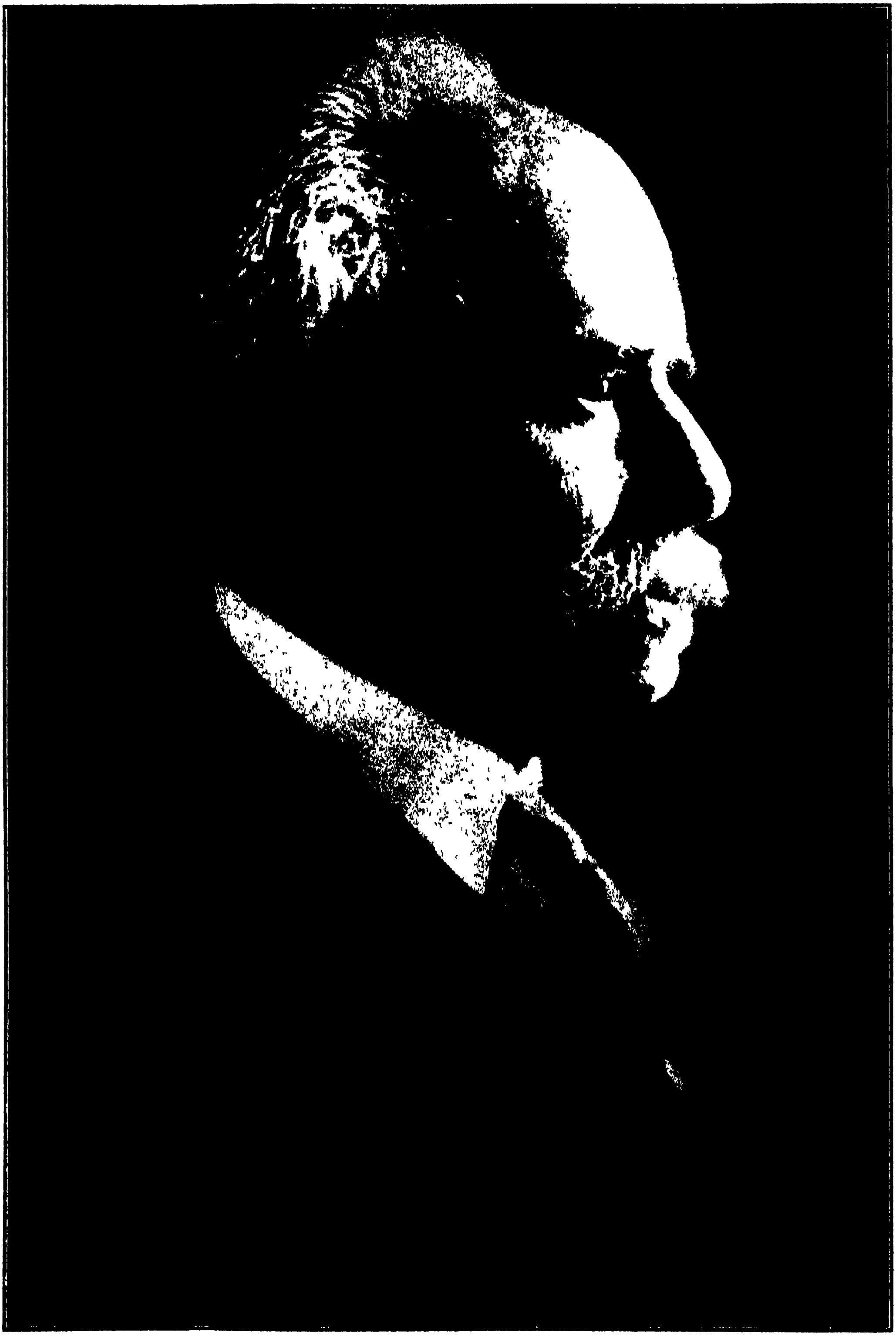
Further study of the data shows a definite fourteen- or fifteen-month period in solar activity to be exhibited both in the matter of sun-spots and in radio reception.

Another important result of the study of the reception curve is to show how completely unfounded is the popular impression that radio reception is universally poor in summer and good in winter. Generally speaking, reception should be better in the winter months on account of the shortened days and decreased daylight. On the other hand, the sun-spots and radio curves of 1926–28 show that the increased solor activity actually gave much poorer reception in the winter months of both 1926 and 1927 than during the summer months of the same years Conditions again improved in 1928, but reception again became poor in the fall and winter of 1929. It may be mentioned that the high degree of static due to thunder-storms in the summer months results in the fact that the average radio listener will decrease the sensitivity of his set in summer to lessen these disturbances with the necessary accompaniment of low audible intensity of distant stations. Hence the general impression of a low intensity accompanying warm weather temperature.

The rise in sun-spot numbers in the fall of 1929 corroborated to a remarkable degree the evidence I ventured at the New York meeting of the American Association for the Advancement of Science in 1928, that the period of maximum for the present eleven-year cycle had not been passed. Forecasting on the basis of the fifteen-month cycle, which had worked so effectively during the last few years, the year 1930 should show a general decrease in sun-spot numbers as the year waxes, with a corresponding increase in radio signal strength in the broadcast zone. By the very end of 1930 and the beginning of 1931, the general rise of a secondary sun-spot maximum may be evident. By 1931, however, it is believed we shall be so far from the maximum of the eleven-year period that the secondary maximum period will have no such marked effect upon radio reception and allied electromagnetic phenomena as have the sun-spot maxima of 1928–29. The general lifting of the ionization level in the earth's atmosphere may be expected to continue with fluctuations through the next six years, but in 1934 solar activity should be as quiescent as at the last minimum in 1923.

Perhaps the most remarkable result of our correlation study has been the discovery that radio apparatus has become an effective tool in the study of solar radiation. Furthermore, since meteorological changes are correlatable with changes in radio reception, it is but fair to specify that a new method has been evolved which may ultimately lead to important correlation between sun-spots and the weather. To this end researches will be continued in these closely related lines at the Perkins Observatiory.

In conclusion, it may be said that investigations in radio transmission, together with researches in the change in the earth's magnetism and electricity and the ultra-violet radiation of the sun, may yet prove to furnish the most definite data as to changes in solar activity itself.



PROFESSOR FRANZ BOAS

THE PROGRESS OF SCIENCE

PROFESSOR FRANZ BOAS, PRESIDENT OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

FRANZ BOAS, president of the American Association for the Advancement of Science for 1931, was born in Minden, Westphalia, in 1858. He was educated at the universities of Heidelberg, Bonn and Kiel, receiving his doctorate from Kiel in 1881. Up to this time his work had not touched the field of anthropology, which he, more than any other person, was to mark out and develop. His dissertation was on the color of sea water, and he undertook what proved to be the first of his anthropological field trips in the pursuit of his interest in geography and physics. This expedition was to Cumberland Sound and Davis Strait, where he spent the better part of the years 1883 and 1884 among the Central Eskimo. Under the influence of Ratzel he had expected to demonstrate geographical determinism, but his appreciation of the far-reaching significance of the forms of the cultural life of this people finally determined his life work. He returned from Hudson Bay with material on the geography of the region, but he had in addition abundant data on the cultural life of the Central Eskimo as well as an ethnographical collection of specimens.

He returned to Germany, where he was assistant in the Royal Ethnological Museum in Berlin under Bastian, and docent of geography in the University of Berlin. In 1886 he undertook ethnological investigations in still another primitive field for the British Association for the Advancement of Science. It was among the Indians of the North Pacific Coast of North America that he began the anthropological field work with which he has identified himself throughout his life. From this time till 1897 he made repeated trips to this region, investigating the cultural life of the various tribes up and down the coast, collecting mythological material and ethnographical specimens, taking measurements of bodily form, recording linguistic texts and making grammatical analyses. After 1897 the work was continued as the Jesup Expedition, and was enlarged to include a number of investigators under his direction.

From 1888 to 1892 he was docent of anthropology at Clark University. He was chief assistant of the department of anthropology at the Chicago Exposition in 1893, and to him was largely due the success of that first scientific exhibition of American ethnology. At the close of the World's Fair he took charge of the collections made there as curator of the department of anthropology of the Field-Columbian Museum, coming, in 1896, to the American Museum of Natural History in New York City where he was assistant curator and curator till 1905 From the time of his coming to New York he was lecturer in physical anthropology in Columbia University, and from 1899 until the present time he has been professor of anthropology at that institution. In 1912, he lectured at the International School of Archeology and Ethnology in Mexico City and, in 1924, at the Institute of Culture History at Oslo.

Besides his life-long anthropological work on the North Pacific Coast Dr. Boas has carried on investigations in Porto Rico, in Mexico and in the Southwest pueblos, and is at the time of his election as president of the American Association for the Advancement of Science spending his sabbatical term among the Kwakiutl Indians of Vancouver Island, the tribe of the Northern Coast with which he has been most closely identified.

Alone among anthropologists Dr. Boas has worked in the three major

fields of anthropology: physical anthropology and anthropometry; linguistics; and cultural anthropology. Archeology is the only branch of anthropology to which he has not made major personal contributions. In his work in physical anthropology he has constantly called attention to the necessity of investigations into the rates and processes of physical change so that we may know something of the behavior of physical measurements under various hereditary and environmental conditions, information that is necessary before we can intelligently use physical statistics as a basis for the classification of human groups. In linguistics he has set a high standard for the recording of primitive languages and for the analysis of their grammatical forms, and has interested himself in the processes of linguistic development and in the use of this material in historical reconstruction. In cultural anthropology he has emphasized the importance of a twofold approach, the one aiming at the most complete and fully interrelated study of the different aspects of the cultural life of any peoples, and the other aiming to place this culture and the different aspects of it in its broad setting as one local variant of much wider distributions. The latter of these emphases has led to his interest in historical reconstruction of those parts of the world without written records, and the former to his insistence on the great rôle played by the forms of institutional life in the psychology of any peoples, and his understanding of the possible equal value of very divergent cultural forms.

It is seldom that one man has been so largely responsible for the history of a scientific discipline as Dr. Boas of anthropology. Almost every American anthropologist has been a student of Boas, and his work in all fields of anthropology has made him a leader in fact as well as in name.

The honors that he has received have been in keeping with his achievements. The degree of LL.D. was conferred upon him by Oxford University and Clark University, the degree of Sc.D. by Oxford University and Columbia University and the honorary Ph.D. by the University of Graz. He was made a member of the National Academy of Sciences in 1900. He was president of the American Anthropological Association from 1907 to 1909, of the New York Academy of Sciences in 1910, of the XXIII International Congress of Americanists in 1928.

For years he has held offices which involve incessant labor, not only of organization and administration but even of financing. He was editor and guiding spirit of the Jesup North Pacific Expedition series and of the American Folk-Lore Society. He is editor of the American Ethnological Society, of the Columbia University Contributions to Anthropology, and of the *International Journal of American Linguistics*, to mention only a few.

He submitted plans and secured funds from the Carnegie Institution for a concentrated drive to get written records of the nearly extinct Indian languages of North America. In less than five years some twenty-three grammars have been written under his direction; the work is continuing and may soon be extended to include Latin America.

His bibliography is extensive, but the following may be singled out for special mention: "The Growth of Children," 1896, 1904; "Social Organization and Secret Societies of the Kwakiutl," 1897; "Changes in Bodily Form of Descendants of Immigrants," 1911; "Tsimshian Mythology," 1909; "The Mind of Primitive Man," 1911; "Kultur und Rasse," 1913; "Primitive Art," 1927; "Anthropology and Modern Life," 1928.

R. B.

THE WORK OF DR. BURTON E. LIVINGSTON AS PERMANENT SECRETARY OF THE AMERICAN ASSOCIATION

UPON the resignation of Dr. Burton E. Livingston as permanent secretary of the American Association for the Advancement of Science, it is appropriate that we express our appreciation of the great contribution he has made to American science during the eleven years that he has devoted to the reorganization of the work of the association, following the adoption of the new constitution at the St. Louis meeting in December, 1919

Many excellent features of the work of the association are now so familiar to us that we are apt to forget that they are recent developments, largely devised and put into effective operation by Dr. Livingston. Among these may be mentioned the Preliminary Announcement and Reports of the Annual Meeting (as they appear in special issues of *Science*), the remarkably interesting general sessions and non-technical lectures that form a conspicuous part of the annual meetings, the Annual Science Exhibition, the Association Press Service, the Association Prize, the Secretaries' Conference, the Academy Conference, the General Program with its convenient system of key symbols, and the method now in use for securing fellowship nominations. Although some of these features originated earlier in the history of the association, their present form and high degree of excellence are due almost entirely to the development that has occurred under the efficient leadership of Dr. Livingston.

The most tangible index of the remarkable development of the American Association under Dr. Livingston's guidance is the extraordinary growth in membership that has occurred during the last decade. The membership has grown steadily at an average rate of nearly eight hundred new members each year. From 11,442 in 1920 it has increased to over 19,000 at the present time. Growth in numbers has been accompanied by a less readily evaluated but even greater increase in interest displayed by members in all aspects of the work of the association. The rapidly growing appreciation of the work of the association and all that it means to science and education in America is shared by members of its one hundred and twenty-two associated organizations, representing all of the many thousands of American scientific investigators, teachers, and friends of science.

Dr. Livingston has shown remarkable executive ability in framing the broader policies of the association that look to the future as well as in handling the innumerable details of administration. He brought to his work an unyielding earnestness of purpose in advancing what he conceives as a great cooperative movement, capable of exerting a powerful beneficial influence upon science and civilization Endowed with sound judgment and rare ability as an executive, Dr Livingston has devoted sixteen hours a day, during the strenuous period before and after the annual meetings, to his combined duties as permanent secretary of the association and director of the Laboratory of Plant Physiology of the Johns Hopkins University. During the meetings his day rarely was finished until three or four o'clock in the morning—with the council regularly meeting at nine

The members of the council and of its executive committee, inspired largely by the permanent secretary, have shown a constantly growing interest and enthusiasm in governing the activities of the association. They have cooperated in every possible way with Dr. Livingston and have depended upon his judgment for many important decisions affecting the policies of the association. The permanent secretary has been helped by a small but exceptionally efficient staff of assistants in the Washington office,

—*Bachrach*

PROFESSOR BURTON E. LIVINGSTON

headed, throughout his term, by Mr. Sam Woodley. And an increasingly helpful cooperation of the section and society secretaries has been an important factor in the growing influence of the association on American science

One of the most valuable contributions made by Dr. Livingston is in the publication of readable and interesting reports of each annual meeting. These generally have filled one whole issue of *Science*, and they are of great interest to all who have attended the meeting as well as to those who have remained at home The Preliminary Announcement, likewise published in a special issue of *Science*, is now a publication of great importance to all members of the association. Few people can realize the enormous task involved in the preparation of these publications, all the material for which has been reorganized and much of it rewritten by Dr Livingston

The Secretaries' Conference and Dinner, organized by Dr Livingston, forms an important gathering at which all the society and section secretaries meet with the executive committee of the association and work out plans by which the activities of the various groups are coordinated. Under the guidance of the permanent secretary the relations of the academies of science to the association have developed in a very satisfactory way An efficient means to this end is the Academy Conference and Dinner, at which representatives of the affiliated academies meet with representatives of the association at each annual meeting

Great service has been rendered by Dr. Livingston in placing the financial affairs of the association on a secure and satisfactory basis. Marked improvements have been made in the financial arrangements for the annual meetings and in the handling of the general current funds of the association Additions have been made to the permanent endowment of the association, the methods of investment of the permanent funds by the finance committee and the use of income from these funds now offer every possible encouragement for additional donations.

Dr Livingston retires from his duties as permanent secretary of the American Association to devote his full time and attention to his academic work at the Johns Hopkins University, where he has been professor of plant physiology since 1909 and director of the Laboratory of Plant Physiology since 1913 One of the foremost authorities in the world on the water relations of plants, Dr. Livingston is author of more than one hundred and seventy-five papers on plant physiology, and of several books, including "Rôle of Diffusion and Osmotic Pressure in Plants," "The Relation of Desert Plants to Soil Moisture and to Evaporation," and "Distribution of Vegetation in the United States as Related to Climatic Conditions" (with F Shreve) He has also translated and edited the English edition of Palladin's "Plant Physiology" A number of instruments devised by Dr. Livingston are used throughout the world in physiological research These include the porous-cup atmometer (for measuring evaporation as a climatic factor), the auto-irrigator (for automatic control of soil moisture of potted plants), water-absorbing points (for measuring water-supplying power of soils), and rotating tables (for assuring equal exposure of plant cultures to environmental conditions)

The association feels very grateful to Dr Livingston for the years that he has devoted, enthusiastically and tirelessly, to its work; it congratulates him on his great achievements as permanent secretary; and it extends to him best wishes for further successes in his own field of scientific research.

SAM F. TRELEASE,
Secretary, Section G,
Secretary of the Council, 1921–30

PROFESSOR EINSTEIN AT PASADENA

PROFESSOR F. H. SEARES, PROFESSOR P. S. EPSTEIN, DR. WALTER MAYER AND PROFESSOR EINSTEIN.

PROFESSOR EINSTEIN AT THE MOUNT WILSON OBSERVATORY

PROFESSOR EINSTEIN, DR WALTER S ADAMS, DIRECTOR OF THE OBSERVATORY, AND WILLIAM WALLACE CAMPBELL, DIRECTOR EMERITUS OF THE LICK OBSERVATORY AND PRESIDENT EMERITUS OF THE UNIVERSITY OF CALIFORNIA

SIR CHANDRASEKHARA VENKATA RAMAN, NOBEL LAUREATE

IN awarding the Nobel Prize in physics for 1930 to Sir C V. Raman, the Swedish Academy concurred with physicists the world over in appraising the discovery of the "Raman effect" as one of the most important achievements in physics in recent years

As on some previous occasions, the award this time is made, nominally at any rate, for a single experimental result of striking importance rather than for a high standard of productivity maintained over a period of years Again as on previous occasions, the particular experiment to receive this signal recognition is a rather simple one one which might have been made with equipment at hand in almost any physical laboratory in the world at any time during the last forty or fifty years Indeed, within a year of Raman's announcement of his discovery, the effect was verified and studied by more than forty investigators in countries other than India

In its simplest form the experiment consists in irradiating a substance composed of molecules with monochromatic light, and observing the spectrum of the light which the substance scatters Raman found that the scattered light comprises, in addition to a line of the same wave length as the incident radiation, a few much fainter lines as well, which additional lines are in a sense satellites of the primary line, moving with it as a group through the spectrum when the wave-length of the primary radiation is altered

In the first definitive experiment of this kind, Raman photographed the spectra of the radiation scattered by various organic compounds when illuminated by a part of the spectrum of a

SIR CHANDRASEKHARA VENKATA RAMAN

mercury are On long exposure the plates revealed these additional or secondary lines not present in the primary light. It was found possible to classify these secondary lines into groups each associated with a single one of the primary lines; corresponding members of the various groups are displaced in frequency each by the same amount from its primary The different groups may overlap in the spectrum, making the sorting out difficult but not impossible A group may extend on both sides of the primary, as a rule more and stronger lines are found on the side of lower frequencies. Such lines as do appear on the high frequency side are found always to be matched by lines of equal displacement on the low frequency side. It is as if the scattering material has at its disposal a small collection of frequencies which it can add to that of the incident light or substract from it, and as if it prefers subtraction to addition These simple numerical relationships distinguish the Raman effect from the somewhat similar phenomenon of fluorescence—these and the fact that the Raman effect appears to be a universal phenomenon observable with any transparent medium gaseous, liquid or solid, whereas fluorescence is exhibited by a limited class of materials only

The simple numerical relationships which have been mentioned as characteristic of the Raman effect, and one other which is to be described further on, are easily explained in terms of light quanta and the known properties of molecules This is one of the reasons for regarding the discovery of the Raman effect as an event of great importance; it makes an addition to the list of phenomena which are conveniently interpreted by regarding light as a corpuscular as well as a wave phenomenon.

Since Einstein in 1906 rehabilitated the corpuscular theory of light to explain the photoelectric effect, and more especially since the discovery of the Compton effect in 1924, it has become steadily more imperative to recognize that light has these two apparently irreconcilable aspects; a beam of light is a flight of particles or a propagation of trains of waves, depending upon the particular phenomenon which is to be explained or visualized. In explaining some phenomena it is even necessary, or at least convenient, to oscillate between the two views at different stages of the argument In such cases we make the translation by means of two well established laws. the energy of the light particles or photons is strictly proportional to the frequency (waves per second) of the associated undulations, and similarly the momentum of the photons is strictly proportional to the wave number (waves per centimeter) of the undulations The factor of proportionality is in both cases the so-called Planck constant h

In the corpuscular picture the Raman effect is due to interchanges of energy occurring in encounters between the photons of the incident light and the molecules of the scattering material. Photons emerge from these encounters with altered energy; they constitute the scattered light of altered frequency and altered wave-length which Raman detected Now every kind of molecule or atom has the following peculiar property: its internal energy is limited to certain definite discrete values The molecule is capable of existence only at certain "energy levels," and can accept or give up energy only in amounts which will raise or lower it, from the particular level in which it happens to be, to another of its levels.

Thus the photons may give up to the molecules only one or another of these characteristic amounts of energy, and, in consequence of the direct proportionality between energy and frequency, the frequency of the associated waves should be lowered only by corresponding amounts It is for this reason that

the Raman spectrum is a spectrum of sharp lines. The frequency displacements in the Raman spectrum should correspond to differences between energy levels of the molecules; and in cases in which these latter are already known this relationship is verified.

The Raman lines on the high frequency side of the primary line may be explained on the general principle that processes of the kind mentioned in the last paragraph are necessarily reversible. If it is possible for a photon to give up a part of its energy in raising a molecule from one level to another, it must be possible also for the molecule in passing in the opposite direction to impart an equal amount of energy to a colliding photon. This process is the analogue of what is known in encounters between electrons and atoms as a "collision of the second kind." The presence of high frequency components in the Raman spectrum symmetrical with the low frequency components is due to such encounters. These components are weaker than their companions because at ordinary temperatures nearly all of the molecules are in their state of lowest energy and are incapable therefore of imparting energy.

Thus, the importance of Raman's discovery is due partly to its revealing a previously unknown process in nature, partly to the additional basis of reality which it affords to the photon, and partly to its supplying a new and convenient method of investigating the energy levels of molecules.

It was remarked earlier on that the Raman experiment is a rather simple one which might have been made with equipment available in any physical laboratory at any time in recent decades. It was no accident, however, that this particular discovery was made by Raman rather than by someone else. Important discoveries in physics, even quite simple ones, are usually made only by investigators who have cultivated intensively the particular field concerned, and this is strikingly true in the present instance. No one else in recent years has been as assiduous in the study of the scattering of light as Professor Raman. True, in the years just following his graduation from Presidency College, Madras, in 1907, his interest —if we may judge from his publications—centered chiefly in the vibrations of mechanical systems—stringed musical instruments in particular—and other acoustical problems. But even in these years problems in optics claimed a part of his attention. About 1920, however —three years after he became Sir Taraknath Palit, professor of physics at Calcutta University—he turned abruptly from studies in acoustics and devoted himself almost exclusively to optics and particularly to investigations of scattering, both theoretical and experimental. Of one hundred papers and notes published by Raman independently or in collaboration with his associates and students since that time, eighty-three deal with problems in optics and forty-nine with the scattering of light.

It speaks well for the development of science in India that Professor Raman apparently owes little or nothing of his eminence to direct contact with physicists in other countries. His formal training was received entirely in India, and, except for a single year, he has worked only in his native land. In 1924 he attended the Toronto meeting of the British Association and afterwards carried on his researches for some months at California Institute of Technology.

His previous honors, which have been numerous, include the general presidency of the Indian Science Congress and fellowship in the Royal Society. Knighthood was conferred upon him by King George in 1929. India may well be proud of Sir Chandrasekhara Venkata Raman, her first Nobel Laureate in science.

C. J. Davisson

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THE FUTURE OF MAN IN THE LIGHT OF HIS PAST:[1]

THE VIEW-POINT OF AN ARCHEOLOGIST

By Dr. A. V. KIDDER

CHAIRMAN OF THE DIVISION OF HISTORICAL RESEARCH, CARNEGIE INSTITUTION OF WASHINGTON

THE archeologist is a hard man to get out of the trenches, by Christmas, or at any other season. He finds so much of interest underground, and he is so comfortable and so quiet in his contemplation of the past that he hates to emerge to be dazzled and confused by the glare and hurry of the present. And as to the future, if he can look forward to a continuing supply of ruins to excavate, he is supremely indifferent.

That, of course, is just the trouble with archeology. When forced to justify his existence the archeologist solemnly states that one can not understand the present without a comprehension of the past. Granted. But he is peevishly resentful if it be suggested that he can not interpret the past save in the light of the present. A paleontologist, it might be remarked, who had never seen a cow or a dog would be puzzled to reconstruct from the fragmentary and disarticulated bones with which he must work the appearance of a primitive mammal. And so it is very good for a digger to be brought out of the ground, to be forced to face the meaning of his finds; to take stock and to determine what, if any, bearing his labors may have upon the present and the future of mankind.

When I was asked to take part in this symposium I felt that for the honor of my profession I must above all things be scientific. I should naturally have liked to assemble some statistics and to have topped them off with one of those splendid formulas that have Greek letters in them. But I've never been able properly to understand the intricacies of the statistical method, besides which no archeologist can ever bear to contemplate the magnitude of his probable error. But I thought that a graph would be the next most scientific thing I could do. So I made one—on coordinate paper—with abscissae and everything—millennia since the Old Stone Age one way, degrees of human progress the other. And I plotted on it the course of civilization. As I had also recently been reading a book on sociology I thought I ought to have a spot-map. So I made one—on Mercator's projection—a little spot for a humble culture, a big spot for a brilliant one, labeled the spots with the names of the races con-

[1] Symposium before the American Society of Naturalists, Cleveland, Ohio, January 1, 1931.

cerned and drew lines between them to mark the peregrinations of civilization.

But when they were all done I found it hard to contemplate them with equanimity, for while, according to my graph, there is a comforting general rise in the line of civilization, its upward course is interrupted by drops proportionate in violence to the speed and height of each preceding peak; and my spot-map indicated that when once a people has lost its position at the top of the heap it can not hope for future preeminence. In other words, my researches might seem to show that our present order is due for a terrific smash and that the next rise will be carried on by a race other than ours.

Of course it is pleasant to feel that there will be another rise and that civilization itself is not necessarily doomed; and perhaps the people who are going to be the next overlords will run the world more intelligently than we do. Nevertheless it is disquieting to consider even the temporary break-up of our culture or the passing of our race. What can we do about it? How can we smooth the curve, how eliminate the perhaps not inevitable drop, how keep ourselves in the cultural running?

What has happened in the past? It is of course the business of the archeologists and the historians to find out. But they have not done so. At least not convincingly. And we do not yet know why former civilizations have withered, nor do we know why their seeds, finding lodgment in new racial soil, have almost invariably produced stronger cultural offspring. A thousand explanations have been offered. The geneticist attributes slumps to bad genes and recoveries to happy combinations of good ones; the nutritionist sees things in terms of vitamins; the epidemiologist in terms of disease; the sociologist perceives faults or virtues in this or that aspect of social organization. And if all else fail, one can always join Ellsworth Huntington in feeling for the climatic pulse.

But it is obvious that no single cause can reasonably be held responsible either for the rise or for the fall of so infinitely complex a thing as a civilization. Civilization seems to grow in response to some unknown but potent force which impels all animate creatures toward better living—in other words, toward more perfect adaptation to their physical and social environments. After a half-century of research we can not honestly be more precise than that. In regard to the fall of civilizations we are in scarcely better case, but we can perhaps so phrase the matter as to pave the way for clearer understanding and open lines for renewed attack by saying that civilizations have fallen because of the failure of man to develop a *savoir vivre,* a knowing how to live, proportionate to his material achievement. If, from Paleolithic times to the present, man had been able first clearly to formulate and then successfully to solve the social, economic and physiological problems forced upon him by his growing culture, he would not have made the mistakes, genetic, sanitary, nutritional, political, military which, singly and in various combinations, have led to the retrogressions that have interrupted the steady ascent of civilization. The human race, it would seem, has always built the machinery of living faster than it has learned to run it. Which is merely another way of saying that it is fundamentally easier to make than it is to think.

And while we are thinking more and perhaps even thinking more clearly than we have in the past, we appear to be following exactly the same path as our forebears. We are failing, just as they did, to develop a social sagacity comparable to our material advance.

In many ways it would appear that

we are even more badly out of balance at the present time than we have ever been before. This, it goes without saying, is due to the unprecedented speed and scope of physical and biological discovery. On the physical side, to cite but one or two instances, the development of labor saving machinery which brought about serious social and economic difficulties a hundred years ago, appears to be inducing a second not dissimilar crisis to-day. Machine-fostered mass production, whose minutely divided jobs destroy all pride of craftsmanship, reduce workers to automatons and produce states of mind which the industrial psychologists tell us are to the last degree unhealthy. Modern transportation and communication have practically abolished space, bringing the peoples of the world into such close juxtaposition that racial tensions are being set up and racial mixtures are going on whose consequences are, to say the least, precarious. The biological sciences together with biochemistry are permitting medicine to reduce infant mortality to an unprecedented degree and thus allowing to grow to procreative maturity countless thousands of weaklings who would not otherwise have survived. And so one might indefinitely go on.

I, and the many more able thinkers who have dealt with this subject, have, as is the habit of Cassandras, stressed its darkest aspects. We are prone to forget that in the make-up of our Frankenstein there is a vast deal that is beneficent. But nevertheless his I.Q. is still lamentably low, and if he turns and rends us it will be because his material strength is not tempered by social judgment. The physical sciences have built him a noble and a terrific body, the humanistic disciplines have not yet supplied him with a brain.

It is thus the failure of students of man, rather than the success of research workers in physics and chemistry and biology, which has brought us to the pass which the graph-making archeologist views with alarm. It would be utterly impossible, even were it desirable, to stay the progress of exact science with its inevitable practical applications. If for no other reason because upon prior findings in physics, chemistry and biology must be based all real advances in humanistic understanding. Our task is therefore to bring the disciplines which concern themselves largely or in part with the less tangible aspects of human existence to parity with their brethern of the test-tube and the breeding-pen.

How can this be done? I'm not sure. The problem has puzzled much better brains than mine. But I do believe that the first and most important step is clearly to visualize and frankly to face the colossal task which confronts us. I think it is necessary for anthropologists and historians and psychologists and sociologists to realize that their problems are as much harder than those of biology, as biological problems are than those of physics. Only by grasping the fact that the inherent intricacy of their subject has made it impossible for them to keep pace with the first rush of nineteenth and twentieth century scientific achievement with its precise and satisfying findings can they be saved from the fatal inferiority complex which has really been at the bottom of so much of their flabby thinking. Furthermore, it is necessary for them fully to comprehend the difficulty of their task if they are to plan a well-advised attack upon it.

The attack has two aspects, the material and the intellectual. On the material side we must have more men and much greater funds for the support of their investigations. In this the material sciences have greatly improved our prospects, for their achievements

have shown so clearly the immense practical advantages of research that the layman is willing, as never before, to provide money for its advancement.

Granted that it may ultimately be possible to apply to the problems of man the energies of well paid and adequately financed workers, there still remains the vastly more important matter of fostering such intellectual attitudes as will permit development of a sound methodology for coping with the intricacies of human life.

In such a statement as this, one is naturally limited to generalities. One can not discuss the interrelation of the various social disciplines. As a matter of fact, one of our main troubles is that they are not interrelated nearly as closely as eventually they must be if we are to get forward. We work too much in compartments, both in subject matter and in our arbitrary divisions of historic time. Man must be considered in all his endlessly complex relationships with his fellows and at all periods of his existence. To accomplish this it is necessary to bring all students of man into close intellectual relationship. But even if this could be done, the social sciences would only be found competent to deal with those aspects of human life which are in essence extraorganic. Man, however, is also an organism and his existence is largely conditioned by biologic laws. Hence no real progress in the understanding of history, in comprehension of the present or in envisagement of the future can be made without knowledge of the action of such laws. Some method must therefore be worked out for free intercourse between biologists and humanists. For the latter it is absolutely essential. I also believe that it would be of value to biologists, particularly to those who give thought to the applications of their research to human affairs. The findings of biology are so concrete and so pleasingly definite as regards rats and fruit flies that there is a tendency to apply them, lock stock and barrel, to the interpretation of the infinitely more complex existence with which culture has environed mankind. This pitfall has as a rule been avoided by the biologists themselves. They have realized, as Professor East points out so clearly in "Heredity and Human Affairs," that extreme caution must always be exercised. But the pseudo-scientific popular writer discovers in the results of biology ready material from which to fabricate the most ridiculous hash: the Nordic myth, for example; certain types of eugenic and psychological propaganda; some of which have done serious practical harm and all of which have served definitely to retard a proper appreciation by the intelligent public of the aims and the potentialities of those sciences.

Close association is needed between the several social disciplines and between that group and the biologists. But the theoretical desirability of such intercourse is naturally never going to bring it about. Every one is too busy tilling his own little patch. Only common interest in common problems can induce true intellectual understanding, active cooperation and the essential pooling of ideas.

How these things can best be accomplished I again do not know. But it is obvious that joint attack upon single fields by groups of workers representing many sciences may be expected to achieve vastly more significant results than the same number of individual studies prosecuted, as is usually now the case, in widely scattered fields. Adherence to this principle has led the Carnegie Institution of Washington to undertake its survey of Yucatan. Engaged in that project are archeologists, historians, sociologists; cultural, linguistic and physical anthropologists, physi-

ologists, epidemiologists, botanists, zoologists, geologists and climatologists. The survey is frankly an experiment, but it is based on the proposition that only by utilizing all possible resources can we expect to progress toward analysis of the vastly complex problems which face us in even so relatively simple an inquiry as that into the history and the present life of the Maya Indians. Further development of this closely coordinated type of investigation is evidently essential if we are to reach understanding of the infinitely more involved conditions which obtain in our own civilization.

Practically, we should doubtless get ahead much faster through such concentrations of effort. We might well expect more intelligent collection of data, clearer classification and sounder interpretation. But of even greater importance would be, I believe, the breaking down of the barriers which modern specialization has erected. Specialization, of course, is necessary, for it is the splitting up of something too large for immediate comprehension in its entirety to permit intensive consideration of its parts. The process, however, implies eventual reassembly of those parts and ultimate visualization of the whole. It is this broad grasp of man's biological make-up, his psychological endowment and his cultural overlay which must be attained if the social sciences are adequately to meet their ever-growing responsibilities. By making every effort to develop thoroughly well-rounded researches we can produce the best possible medium for the stimulation of synthesizing minds, and I am confident that under such conditions the humanistic Darwins and Einsteins will, in due course of time, appear to show us the way out of our difficulties.

I opened pessimistically, but I seem to have worked myself into a better frame of mind, and I close in the most approved Hollywood manner—a fade-out of a closely united scientific family with a whole litter of little super sociobiologists cooing in their cooperative cradles.

THE FUTURE OF MAN IN THE LIGHT OF HIS PAST:

THE VIEW-POINT OF A SOCIOLOGIST

By Professor WILLIAM F. OGBURN
THE UNIVERSITY OF CHICAGO

IT is not yet given to the sociologist to see clearly into the future. And when he so ventures he can not see far. The astronomer looks with accuracy millions of years into the future, we think. The paleontologist's unit is large. The biologist's scale is the generation, but he knows that many thousands of generations may pass without appreciable biological change. The sociologist, however, is usually content to try to predict a few months ahead as, for instance, when the business depression will end, or who will be our next President.

When one looks into the future it is well to recall as a sort of precautionary measure the scant success that has been met by most of those who have been so foolish. For instance, that dean of science, Simon Newcomb, who could predict to the second a future eclipse of the sun, wrote in 1903, "The example of the bird does not prove that man can fly. . . . There are many problems that have fascinated mankind since civilization began which we have made little or no advance in solving. . . . May not our mechanicians . . . be ultimately forced to admit that aerial flight is one of that great class of problems with which man can never hope to cope, and give up all attempts to grapple with it?"[1] Yet just two months after Newcomb made this remark the Wright Brothers made their first flight at Kittyhawk, N. C. The scientist may be expected to err on the side of conservatism, but hardly H. G. Wells, who wrote in his "Anticipations," "I must confess that my imagination, in spite even of spurring, refuses to see any sort of submarine doing anything but suffocating its crew and foundering at sea." The fact that developments have occurred which these men said could not happen may be taken as an encouragement to be bolder. Yet few social scientists have ever so dared. I did hear, however, of some thirty-one predictions made before 1900 regarding the development of the ship,[2] only six of which materialized. But even so high a percentage of successes as this may also be taken as an encouragement to proceed. Perhaps my batting average will not be so high, and my predictions may be like those of Mr. Astor, who wrote in 1903 that "second story sidewalks, composed largely of translucent glass, leaving all the present street level to vehicles . . . will doubtless have made their appearance in less than twenty years."[3]

Yet there have been some responsible forecasts that have come true. Francis Bonynge,[4] for instance, predicted in 1852 the population of the United States

[1] Cited by Mark Sullivan in his "Our Times: The Turn of the Century," p. 366, from *The Independent*, October 22, 1903.

[2] Cited by Mr. Colum S. GilFillan.

[3] Cited by Mark Sullivan in his "Our Times: The Turn of the Century," p. 369, as appearing in the *New York World*, May 10, 1903.

[4] Francis Bonynge, "The Future Wealth of America," 1852, cited by P. K. Whelpton, "The Population of the United States, 1925 to 1975," *American Journal of Sociology*, p. 254, September, 1928.

50 years ahead, decade by decade, within an error of 5 per cent. Prediction in sociology deals with the environment of man rather than with biological man himself. Man has an unusual environment peculiar to himself alone and not characteristic of the lower animals. It is the environment which Herbert Spencer called the superorganic, which Tyler called culture, and which Wallas called the social heritage. With Eolithic man it must have been very small indeed, a little large in the time of Chellean man, growing slowly up to the last of the men of the old Stone Age. With Neolithic man it became much bigger and more rapidly growing, until in modern times it has become the great thing we call civilization in the largest sense of the term. The sociologist then looking into the future of man tries to see what is going to happen to the superorganic, this new environment peculiar to man.

Prediction in sociology rests on two methods. One is the simple extension of a trend line. But generally such a procedure is only approximately reliable for even a short time. If the trend is a sharply bending one, an extension of the curve beyond a few units of the scale may quickly take one into absurdities. Thus on this basis the ship in seventy-five years would be a mile long. The compound interest curve can not ever go very far in a real world.

The other method is the projection or consideration of the factors that determine the particular trend under consideration. For instance, the factors affecting the length of ships would be many, among them, length of docks and depth of harbor. Again the factors making population growth are immigration rules, growth of income, medical progress, diffusion of birth control, etc. So that by the extension of these factors forward in the form of birth rates, death rates, by age and social groups, and by other means, the curve of population may be projected forward.

In either case the shorter the extension of the curve the less wide the possible error. Projections are of course always in terms of the units in which they are plotted. Thus if the unit is a thousand years, then a projection of five units would mean a projection forward of 60,000 months, a very long time in months, but a short projection in units.

One curve that has been run back with indifferent success for around a dozen centuries is the curve of inventions and scientific discoveries. It is a curve bending so sharply upward as time goes on, that even if the inadequate records of the past get progressively worse and enormous numbers are lost, it is still thought that the line would be one curving upward.

The projection of this curve shows then for the future an increasing number of inventions and scientific discoveries. An analysis of some of the factors making the curve leads to the same conclusions. For instance, the number of inventions and the rapidity of their occurrence are functions of the number of elements in existence out of which inventions and discoveries are made. And generally inventions are not wholly replacements but additions to the total supply of elements. In other words, inventions and scientific discoveries are accumulative and as the pile accumulates, more and more inventions are made, since they do not appear to be restricted seriously by the limitations of human wants.

So in the future environment of man one sees an increasing number of inventions and discoveries, occurring with greater rapidity. This of course means change. It is customary for us to say that we are in a period of transition, implying that we are changing, amidst some confusion no doubt, from a more or less stationary past to some future condition of quiet and peace. The idea is that of a slope from one plateau to

another. But it is thought that this plateau toward which we are said to be moving is a fiction, the creation solely of a hope that looks forward to a haven of rest. But there appears to be no rest ahead for the conservatives, although the differences in the significance of the inventions seems to mean a somewhat undulating movement upward in the growth of material culture. Nations rise and fall, and peoples carrying a civilization shift their relative positions toward priority, but for the world as a whole the total variety of inventions has more or less steadily increased.

Man, the animal, has problems ahead in adaptation to this new environment of material culture. Each invention means a new problem of adaptation for mankind. Women have not yet adapted themselves to the tin can, although one of their adaptations in part was woman suffrage. Families have a problem in adapting themselves to contraceptives. We are not well adapted to factories. Our death rate is still greater in the newer cities than in the older rural cultures. So inventions mean social changes and problems of adjustment. The lower animals have a simple natural environment toward which to make an adaptation, as was also the case of early man. But modern man has a huge cultural environment to which he must adapt himself—a huge culture that is whirling through time, gaining size and velocity as it goes.

It seems to be something of a strain on the young infant to accomplish the feat of adaptation to this environment, judging by the numbers of problem children and the vast extent of mental disorders that follow. A young person used to get pretty well acquainted with his culture by the time he was fifteen or sixteen years old, but now infancy and education are prolonged and we find students in school until their late twenties or even later. In the future when the culture shall have grown much bigger and more complex, how shall this problem be met? Perhaps by prolonging infancy to, say, thirty or forty years or even longer?

More probably in the future there will be seen fewer attempts to learn it all and more attempts to learn only a part of what is to be learned. In other words, there will be specialists speaking a specialist's language; that is to say, a language not very intelligible to the non-specialists. It is said that even to-day some specialists, to wit, mathematicians and geneticists, have difficulty in understanding the language of some of their fellow specialists. But there will also be another language which these specialists all speak whatever their specialties may be. This language will be the product of the standardization and diffusion which follows upon the developing means of communication, that is to say the common language of the movies, the radio, the press, the advertisers, television, ready-made clothes, standardized goods, etc.

The great growth of communication through inventions in this field has the effect of negativing somewhat the aforementioned tendencies of culture to accumulate because it facilitates substitution instead of addition. For the earth as a whole communication is a leveling and simplifying process. Inventions in the field of communication then are some of the limiting factors that will prevent an exponential curve from being carried out in reality as it could be done on graph paper.

The society of the future then will be one of greater and greater change. And as the environment changes the habits of man change. Under these conditions morality, as it is generally conceived, will have no place. For the general notion of morality is the following of a set of rules or commandments. Such commandments can be laid down with

great specificity in a stationary society where experience leads to guidance in minute detail. But in a society undergoing great change there is little guidance to be gained from the past. The situations that arise are new, and ethical conduct is a matter of intelligence and forecast; and the fixity and detail of right and wrong give way before social expediency.

So also the attitude toward law will be very different. Our present ideal is that "the law is the law and it must be obeyed," though perhaps we do not live up to this ideal as well as did the Medes and Persians. But regrettable as it may be, law under a changing society can hardly have the force it has in a stationary society. Under a changing society it becomes very difficult to make rules that will last and hence that will be fully obeyed. It seems also inevitable that many rules, *i.e.*, laws, will have to be made, because of the velocity and bulk of culture. Some of these will be experiments and attempts to make men form new habits. So then the laws will assume less and less of a majestic nature. This does not mean of course that there will not be penalties; but rather that the divine element in them will be less and the human element more.

The technological progress, which will be advancing even more rapidly in the future, will of course not be confined to cities, but will spread to the countryside. Farm and factory joined together on the same land may well be in prospect. Where the foodstuffs grown yield by-products, factories for obtaining these by-products may be located near the farms, since electric power will be readily available. The folkways and manner of living among farmers will resemble more what they are in cities. Such is the magic of the newer methods of communication. Technological progress will mean, however, only a slight substitution of production in the chemical industry for production by the soil, sun and rain, since the latter are not so costly.

But the technical improvements will mean a greater efficiency for the food grower, so that fewer and fewer growers of foods will feed more and more consumers. And if population of the United States approaches soon the stationary point, then we may expect to see the sub-marginal lands turned back into forests, inhabited by wild game. But we shall hardly bring the Red Man back into his ancient home, though that would be scant justice.

It may also be that the cities will lose somewhat their identities. City limits are becoming less and less significant, being broken down by transportation systems and other similar agencies. The suburbs and the country immediately surrounding cities are highly urbanized, so that metropolitan regions are really replacing cities for certain purposes. In the future then the whole nation will become urbanized. There will of course be large centers where the density of population will be great, even though the easy distribution of electric power will occasion the growth of smaller centers. Man is a gregarious animal and the conditions of his future environment will give expression to this gregariousness.

It seems also very probable that the society of the future will have a somewhat different organization. Man, like the ants and bees, has a highly developed social organization, and in the future a still higher development is expected. The units of organization will tend to be much larger, due chiefly to the speed of transportation and the facility of communication over long distances. This statement is not to be taken as implying that the size of the physical plant will necessarily grow larger. There will of course be the greatest variety in the sizes of the

plants. The ultimate limit of this growth of organization is the world limit. Even among the smaller organizations unsuited to such development, there will be certain types that will be chained into much larger federations.

It may also be expected that the heterogeneity of the future material culture will call forth a great variety of organizational effort. The simplicity of the social organization of pioneer days is gone. Organization is a remarkable tool for getting things done and the law of survival will mean a great organizational development, despite some sacrifice of personal liberty and individualism, characteristics which may have a variety of other ways of expression, however. How these developments will affect the state is not clear. The tendency, however, seems to be toward larger organization, despite the setback occasioned by the Treaty of Versailles. One also thinks that a simple scheme like that of democracy will not be so successfully applicable to an actual distribution of power among the varieties of great organizations.

The growth of material culture does not mean that all property will be thus collectively organized. On the contrary, there is to be expected a multiplication in variety of smaller machines which will be personal property and on which the single individual will be dependent along with the multiplication of large machines found in factories on which man is so dependent. The pioneer to America required remarkably few fabricated objects, somewhat more, however, than the American Indian. But now man is dependent upon quite a variety: typewriters, fountain pens, mechanical pencils, tooth brushes, eyeglasses, radios, phonographs, refrigerating machines, stoves, watches, clocks, automobiles, golf clubs, books, scales, brushes, cigar lighters, cigarette cases, can openers, sunlight machines, etc., etc. It is clear that man has become more and more dependent on the smaller machines and tools and it is probable that the future will see the above list extended greatly. Pioneer settlement is increasingly difficult to-day because man must carry with him not only a great variety of tools, but also a great organization which will supply him with products from the big machines. The lower animals that migrate have no tool kit, primitive man had only a very small one, but modern man must take civilization along with him.

Technological progress means increase in the facility of transforming the products of the soil of the sea and the minerals into objects that fulfill man's wishes. Thousands and thousands of tools now do this work, and in great quantities because of the power from coal, oil, wind and water. These discoveries in power and new discoveries in raw materials that can be transformed will bring wealth and abolish poverty. Malthus saw the geometric increase in population, but he never saw the geometric increase in technology. The wealth or poverty of a people is dependent on three things: the status of technology, the supply of natural materials to be transformed into useful objects and the quantity of people to be supplied.

The future population has been much predicted. All are agreed, however, that the rate of increase in Western Europe and in America is slowing up. It seems probable that with the spread of the use of contraceptives the Slavic groups will also slacken in their rate of increase. The Orient and the backward peoples may increase more rapidly for a while but perhaps there, too, a slowing up is to be predicted. In fact, a declining population is altogether a possibility. So then with a restricted population, a rapidly growing technology and with perhaps a slightly growing base of materials

to be transformed, we should expect to be untrue the often quoted prediction of Jesus—"the poor ye have with you always."

If the use of contraceptives is extended radically, it will mean a revolution for women and children. There has often been discussion of how far the birth rate will fall. There is no numerical conclusion, but the answer is that the production of babies, like the production of potatoes, will be governed by the law of supply and demand. If the production of babies falls very low, the value of the baby will rise, according to sound economics. This appreciation of children will show itself in better kindergartens, playgrounds, schools. Apartment house owners will be glad to take families with children, but the valuation of children may be so great by that time that parents will not let them grow up in such a hostile environment as a modern city apartment. The domesticated animal usually has trouble with the breeding processes and man is no exception.

With a scarcity of children and the wealth that comes from technological progress, education in its higher branches will be much more nearly universal. The spread of higher education will be more rapid than the growth of vocational opportunities utilizing this educational content. The result will be that common laborer will be well versed in philosophy, and plumbers will discuss Aristotle—for they will still be quoting Aristotle—as well as members of the professions.

The scarcity of children will mean not only that they will be appreciated more, but that women who bear children will similarly be more highly valued. This increased value will command a price, and that price will be more opportunity. Under the circumstances society will be willing to adjust office and factory to part-time work, if indeed the hours of labor in the working day be not already short enough. Most of the differences in the social status of men and women can be traced to the fact that women not men bear children and rear them and as the birthrate falls these differences will be lessened. There are no peoples known even among primitive groups where there is not a division of labor between males and females, and it may be that some division of labor will continue to exist. But no society has had the reduction in the function of bearing and rearing children that the society of the future with its schools, nurseries, etc., will probably have.

The family organization will continue to lose in the functions it performs unless some new inventions are made that will bring industry back into the home. Electric power together with a multitude of electrical machines would seem to have the potentialities of restoring the home to its former magnificence, if it were not for the competition of industry outside the home. The overhead costs of home machines will be a factor that must be considered, as truly as the efficiency of factory production outside, which will continue to increase. It seems probable that the decline of the social rôle of the family will continue and that its chief functions will be affectional and in some instances educational. The stability of the family will then be as stable as affection is stable. And experience seems to indicate that affection is somewhat variable, at times even fickle. So separations and divorces are expected to increase even more than at present, particularly in the younger years of married life. But the family will hardly disappear. No primitive people has ever been found, no matter how low the scale of culture, that did not have a well organized family. Still, the society of the future may reduce the family functions a good deal more than is found among primitive peoples.

In the future there will also be a really great development of recreation. Man's capacity for recreation is enormous. But this great development will be encouraged because of the specialization of labor, the decline of superstitious religions, the menace of mental disorders and growth of economic surplus. It is recognized that there are various competing forces as in greed, in the love of power and in ambition. But they have not been for humanity as general a disciplinary force as hunger. So sports and recreations of all kinds are expected to flourish and to be the most serious hindrance to the spread of education among adults.

These then are some of the trends which seem probable to a sociologist, who necessarily sees the future of man in terms of the future of society. Spencer conceived of evolution as occurring on three planes, the inorganic, the organic and the superorganic. The superorganic is the subject of study of the sociologist, and he knows something about the nature of its growth and development. Somewhat, though not to the same degree of thoroughness, as the biologist knows the processes of the growth and development of the organic realm. The future of the superorganic can not be seen with comprehensiveness. Only here and there do the probabilities of trends seem well marked. The projection of these trends into the future have been made without considering biological evolution. And to a certain extent the changes in the superorganic are dependent upon the changes in the organic. For instance, if babies could be grown in bottles as biologists suggest as a possibility, this would not be without effect upon the family. The trends pointed out above would be accentuated. So also if the injection of a skilfully balanced proportion of secretions from the ductless glands would at once make a man a Christian, then endocrinologists would replace preachers and the evolution of religion would be profoundly affected. Or if biologists could discover some way of telling which normals carry defective genes, the effect would be profound for all society. But it hardly seems worth while to take time discussing the future of a society where men, say, are produced synthetically in a chemical factory, when the latter event is so remote and so improbable. There is, however, always the contingency that some biologist may come along and upset the predictions of the sociologists —but it seems more probable that it will be an inventor who will do it.

THE FUTURE OF MAN IN THE LIGHT OF HIS PAST:

THE VIEW-POINT OF A GENETICIST

By Professor E. M. EAST
BUSSEY INSTITUTION, HARVARD UNIVERSITY

ANY serious claim to foresee what is actually going to happen to the human race at any future period is undoubtedly a pretension unworthy of a scientist. I say this in order that no one will make the mistake of believing this symposium to be an effort at prophecy, with the contributors posing as oracles. Such vision is given only to statesmen and to fundamentalists.

Estimates of probable trends based on past experience, on the other hand, have proved useful in all sorts of industrial pursuits. It would be possible to defend our undertaking, therefore, as an attempt to utilize available data in plotting the course along which mankind is moving, in order to determine, as nearly as may be, what lies a little further on; for it might then be possible to mark out a new course which would lead to a more desirable destination. Perhaps this sort of thing is what our worthy president had in mind when devising the program; but I suspect that he was subtly planning quite a different assembly, in the nature of a clinical experiment, with the audience and the speakers serving as material. It ought to work in this way. Every statement that is made should act as a small quantity of antigen injected into the cerebral cortices of the members of the society who have been kind enough to attend. The production of antibodies should take place immediately. In other words, each subject will start to think about the topic under discussion and will perceive at once that the speaker has overlooked all of the really important factors in his equation and hence has been led to announce decidedly erroneous conclusions. I am thoroughly in favor of such experiments and hope that this one will be successful.

The first point which each speaker has had to determine, I suppose, is the period with which to deal. We must decide how far into the future we shall undertake to extrapolate our curves. And if we select different dates this does not mean that conditions at the least distant one will be pictured most accurately. It depends upon what variables are chosen for consideration. An astronomer, dealing with a few precise laws of motion, may calculate eclipses a million years ahead with a high degree of confidence in the accuracy of his predictions; a politician has little chance of forecasting the probable course of the next election. The sociologist, therefore, can treat the near future most advantageously. The anthropologist can deal with more distant epochs. He has one of the attributes of deity—a thousand years in his sight are but as yesterday when it is past. The geneticist stands somewhere in between. Perhaps, for him, the year 2500 will serve as a convenient date. After all, the 570 years between then and now include only twenty generations or so—twenty new distributions of the genes.

What, then, will be the probable condition of the world in the year 2500?

Since there is but half an hour at my disposal, I shall confine my speculations to three points: (1) the population of the world and its genetic constitution; (2) the genetic philosophy to which this population may be expected to subscribe, and (3) the probable biological discoveries which have genetic aspects.

The population of the world should be about 3,500 millions, or twice the census figures of to-day. The last doubling took about 90 years; the next doubling may be expected to take about 500 years; and from this point on, there should be very little increase. This figure will seem small to the imaginative geniuses who predict that the chemist will abolish agriculture during the next century by producing all of our food constituents synthetically, or by growing particularly tender beefsteaks and delicately flavored lamb chops in huge vats of culture media. I regret being commonplace; but, having given considerable thought to potential sources of power and raw materials, to the efficiency of laboratory processes, and to other possible factors in the move toward annulling the operations of the Malthusian law, I can develop no greater enthusiasm over the romantic predictions of this type—as, for example, those of the Earl of Birkenhead[2]—than I can over a fresh announcement that Congress is going to investigate a new perpetual motion machine.

The chemist will undoubtedly perform many wonders in the near future. He will learn how to make the fibers, the drugs, the oils, and the other commodities which are to-day obtained from animals and plants. He will manufature vitamines and hormones. And he will be able to produce synthetic carbohydrates, fats and amino-acids. But with the exception of commercially hydrolyzed cellulose, these food products will be laboratory curiosities, for the chemist will be unable to obtain power and raw material at a sufficiently low figure to enable him to compete with the private factories run by the lower animals and the plants.

Though the average birthrate for the world as a whole will probably continue to fall during the next century, no matter what conditions are confronted, the difficulty of obtaining power at a low cost is going to be the determining factor in fixing the population limit and in setting the pattern of future civilizations.

The oil age will soon pass, and in 500 years the reserves of worthwhile coal will be running low. The ingenuity of man will then be taxed to the utmost to keep up with the demands for more and more power. No doubt he will solve the problem after a fashion, though there is no good reason to believe that he will solve it in a wholly satisfactory manner. It does not follow that because man has devised means for disposing quickly of Nature's gifts of fuel, he is thereby qualified to invent low-priced substitutes. The prodigal heir is not usually the perfect business man. The extreme difficulty of the task is apparent if we are not led astray by Birkenhead's nonsensical dream of unlocking atomic energy. There are just five prosaic possibilities—water, tides, wind, sunlight and earth-heat. Ordinary water power, when completely developed, can furnish less than ten per cent. of the world's needs. Mankind will have to fall back on the other four sources, and their utilization will require extraordinarily expensive mechanical equipment. I have no idea as to which source will be tapped, or how satisfactory the results will be, but I am convinced that any such method will be decidedly more costly than digging coal. Haldane puts his trust in wind, though this may be

[2] "The World in 2030," by the Right Honorable The Earl of Birkenhead, P.C., G.C.S.I., D.C.L., LL.D., D.Litt., N. Y., Brewer and Warren, 1930.

only a simple reflex due to reading the London *Times*.

For these reasons, it seems likely that the world will go on without the radical industrial revolutions which so many people fondly expect. Agriculture will probably continue to be the fundamental occupation of mankind for thousands of years, just as it has been in the past. The grave difference between the future economic situation and that of the present era will be due to the fact that agricultural efficiency per man-power is working toward the point where less than 20 per cent. of the world's inhabitants will be required to feed the rest. Industrialization must increase proportionately, therefore, in order to give occupations to the men released from farm work. If this process can go on as far as it is possible, theoretically, for it to go, then each person will be provided with more and more mechanical servants and will receive greater and greater quantities of material comforts. Personally, I am inclined to believe that this trend will have reached its peak before 500 years have passed, and that then a back-to-the-land movement will be required because industrialization will have reached a period of diminishing returns. If the population shall have approached a stationary condition before this date, no extraordinary economic dislocations are to be expected; but if the population should increase to the limits permitted by the earlier economic prosperity, it is unlikely that violent disturbances can be avoided.

Assuming that the population of the earth will have mounted to only 3,500 millions during the next 500 years, and that this increase will have taken place under a constant trend toward greater industrialization, what will be the situation from the genetic point of view?

As I see it, the world will be populated by hybrid mixtures of all kinds. Many relatively pure specimens of the yellow race will be found in eastern Asia, many similar representatives of the white race will be found on the other continents, and samples of the black race will be found in Africa; but, in the main, the inhabitants of the earth will be a rather heterogeneous lot. This process has been going on with increasing rapidity during the immediate past, and all signs point to a still higher velocity of the reaction in the immediate future.

In order to visualize this trend in undistorted perspective, we must take into consideration both the sociological factors and the artistic factors which have an influence in this direction.

It is especially important to realize that, though the world is likely to be supporting only 3,500 million people in the year 2500, it will probably have a population of about 3,000 million by the year 2100. At this earlier date, we may feel assured that all easily colonizable portions of the globe will have become fairly densely populated. Most of this expansion will be due to the efforts of the white race in Africa and in North and South America. In these territories the struggle for survival between the newcomers and the aboriginal inhabitants will soon grow more and more severe. As racial entities, the blacks and the Amerinds will then tend to disappear. Their remnants will be absorbed into the white race. In Asia changes will occur of like character though not of like degree. Asia already contains some 400 million of the so-called brown races, which are mixtures of at least two, and perhaps of all three, of the primary groups. Since they will probably be unable to gain any acreage which they do not hold to-day, we need not consider them further in this connection. But the yellow race will expand to the north and the west, if not to the south, and in this expansion there

will be a further tendency to unite groups having diverse genetic constitutions.

There are plenty of solid sociological impediments to happy interracial unions to-day; but really there are only two arguments that have a biological basis. There may be whole races that are vastly inferior to others. The members of the yellow and the white races believe that they outrank the black race as a whole. The more advanced tribes among the negroid group feel that they are immensely superior to the pygmies and negritoes. The Japanese look down upon that Caucasian remnant, the Ainu tribe. The Caucasians, as a group, recognize no equality with themselves among the poor relations of the Mongolians that they have met here in the Western hemisphere. And there is considerable evidence to support these beliefs. Second, it is possible that some races exhibit a genetic incompatibility with each other, which causes disharmony in the anatomy of the resulting progeny. Apart from these matters, interracial antagonisms are largely a matter of ignorance. Can one doubt that when the turn of a button on a perfected stereoscopic television radio apparatus will, for all practical purposes, put one in the physical presence of the art, the literature and the social customs of any given people, all mere prejudices will soon break down?

As I visualize conditions, then, long before the year 2500 the heterozygosity of mankind will have increased manyfold, with all the possibilities for the production of ultra-idiots and infra-geniuses that such a mixture of genetic differences entails. One may assume that this situation will bring about some very important sociological changes, though what they will be is difficult to say. I do not believe that national aspirations will be weakened, for national solidarity is not built upon a basis of racial homogeneity or of lingual similarity, but rather upon tradition. Nor do I believe that a world union of any kind will be promoted. War will probably continue to be *the* great adventure of the human race. But, in order to gain full satisfaction from the radio-electric devices which will be in common use at this time, it will be necessary for every educated person to be conversant with a universal language. This will raise to the nth power the possibilities of that powerful tool which aligned nations against each other during the great war. I speak of propaganda. Imagine propaganda being spread to a thousand million television radios throughout the world in a language understood by every one. It is hard to say whether the gain in intellectual liberalism which will undoubtedly accrue to our descendants through better opportunities to become familiar with world conditions will more than offset the increased bigotry which will be induced by the vast number of lies which they will swallow.

You may ask how such matters relate to genetics. Perhaps the connection is not particularly close. Yet is it not true that propaganda available to every nation, indiscriminately, will be likely to break down whatever racial solidarity is left at this time? To-day English speech is a greater bond than English blood. An accepted Esperanto or Ido, together with a tenfold increase in racial hybridization, will help produce political alliances which are now quite unlikely.

Extended racial intermixture during the first part of our 570 years will prepare the way for a second development which has the highest genetic interest—the adoption of a eugenic social system, through necessity, as a move toward self-preservation.

Society has always been stratified. Until modern times, this stratification

has, nominally, had something to do with heredity, though its genetic basis was unsound. During the past few centuries, the division in the more enlightened countries has been economic. It, also, has been genetically unsound. Yet both of these arrangements—the feudal aristocracy and the capitalistic aristocracy—have had genetic value in a statistical sense. Havelock Ellis has shown that, during the last three centuries, the lower classes in England have produced a constantly diminishing supply of great men in proportion to their numbers. The great men rose from their classes like cream and, like cream, they were pasteurized.

Nations which have had a great deal of racial intermixture have developed more extreme caste systems. We need not point to India as an exemplification. We find a similar disposal of the population in the West Indies, in Mexico, in South America. It will follow, as the night follows the day, that an almost universal policy of racial amalgamation will beget an almost universal series of caste systems. We hope that they may be founded upon genetic principles. If they are, there is great hope for the future of the human race. If they are not, the situation is rather hopeless; for, no matter how little average difference in physical and mental worth there is between races, there is an immense spread between the best genetic constitutions and the worst genetic constitutions possessed by individuals.

I need not describe the eugenic philosophy which society might well adopt now, and which it must adopt later if racial decay is to be prevented. The laws of selective breeding are sufficiently well known to all who are here. But I must say a few words about the practical application of these laws in a eugenically-minded society.

I do not assume that society will apply a eugenic totem system to marriage and reproduction. It is unlikely that there will be one set of aristocratic gene-carriers and one set of proletarian gene-carriers who are not allowed to intermarry; for this would be both impracticable and unbiological. Instead, every effort will be made to adopt a flexible system which will encourage reproduction among the worthy of all economic groups and which will discourage it among the unworthy. It is probable that the discovery of tests for detecting carriers of defective genes will make the application of such a scheme easier than would be the case to-day. And even if it is impossible to develop such tests, it will not be so difficult as many people think to work out a policy having a reasonable degree of effectiveness. In a twenty-sixth century society science will rule. The intelligent portion of the population will then realize that it is as much their duty to have a certain number of healthy children as it is not to have any unhealthy children. The unintelligent portion can be kept in hand in other ways. It is only necessary for them to be made to understand that unscientific humanitarianism is a bygone relic of the twentieth century, and that public aid, suffrage and relief from taxation are forthcoming only if the eugenic ideals of the state are advanced.

I have no doubt that this type of proposal will sound silly to most of the members of the present generation; but if interracial hybridization becomes as wide-spread as I have pictured it, and if social sterilization of the fittest continues as it has in the past, nothing less drastic will prevent racial deterioration. This conclusion follows because of a genetic point which seems to have been overlooked by otherwise competent writers on the subject. It is this: Genes have no immortality *per se;* they must be kept in the living network of descent. It is quite true that if it takes

10,000 genes to produce a man, then as long as there are human beings, each individual will possess these 10,000 genes. But the difference between genius and stupidity may be due to 20 plus genes in the one case and to 20 homologous minus genes, in the other case, and there is nothing to guarantee that any or all of these plus genes will not be lost. It is by no means certain that the England, France and Italy of to-day—countries of which the United States is a biological part—possess all of the genetic potentialities which they had during the days of the Renaissance, or that Greece can have another Periclean Age when governmental conditions are favorable.

In this connection, let me cite a statement from a paper in the current issue of *Harper's Magazine*. Mr. Harold J. Laski, who is expert in many lines, discusses "The Limitations of the Expert" who is expert in only one line. The expert, says Laski, "too often, also, fails to see his results in their proper perspective. Any one who examines the conclusions built, for example, upon the use of the intelligence tests will see that this is the case. For until we know exactly how much of the ability to answer the questions used as their foundation is related to differentiated home environments, how effectively, that is, the experiment is really pure, they can not tell us anything. Yet the psychologists who accept their results have built upon them vast and glittering generalizations, as, for instance, about the mental quality of the Italian immigrant in America; as though a little common sense would not make us suspect conclusions indicating mental inferiority in the people which produced Dante and Petrarch, Vico and Machiavelli. Generalizations of this kind are merely arrogant; and their failure to see, as experts, the *a priori* dubiety of their results, obviously raises grave issues about their competence to pronounce upon policy."

This is too much, even from the professor of political science at the University of London. One would not expect Mr. Laski to have learned anything about the validity of results secured by the intelligence tests. In the first place, the work was done in great part by Americans; in the second place, Mr. Laski long ago took the stand that this phase of psychology is "the lunacy of a realist," in which he does not choose to believe. But one might expect the conclusions to exhibit a little more logic and a little less sentimentalism. Mr. Laski knows perfectly well that no psychologist has drawn any inference as to the mental capacity of the Italian nation from intelligence tests given to small groups of Italian emigrants. Such conclusions as have been drawn are concerned solely with the comparative ratings of the groups listed. But this is not the point to which I wish to draw attention. The most recent genius cited is a third rate historical philosopher of the seventeenth century. The other three are really great minds of the thirteenth, fourteenth and fifteenth centuries, and have a critical rating in the same order as their birth. Other names might have been cited. There is no gainsaying the preeminence of Italy during the Renaissance. But why has it not occurred to Mr. Laski that it is quite possible that the gene complexes which drew the pattern of civilization during this period are not now functioning in profuse quantities—in Italy, France or England, or, by the same token, in the United States? And the gentleman talks of arrogant conclusions!

Let us now take a few minutes to consider the biological fashions of this time 500 years ahead. Its most singular feature, according to Haldane, will be the production of ectogenic infants. In fact, Haldane's vision of incubating artificially fertilized human eggs on nutrient solutions has so intrigued

Birkenhead that he takes ten pages of prophetic scribble to discuss its possibilities. This is all very well. There is a reasonable expectancy that the thing may be accomplished. It is also a reasonable expectancy that mankind will discover how to induce parthenogenesis. But there are several good psychological reasons for thinking that neither of these processes will ever become popular. Woman will not relinquish the experience of motherhood just when science has made it easy for her; and man will probably rebel at being nothing but a figure of speech. I have great respect for biological chemists and other workers in applied biology, but I think that they will occupy themselves along other more practical lines. We may mention a few samples, for on this phase of future development predictions can be made with some degree of confidence.

We may assume that parasitic diseases will be practically eliminated. It is no mad optimism to feel that those infectious organisms which must have human hosts will be extinguished completely. But progress along this line does not mean that mankind will be freed from all fear of disease, or that the total span of individual existence will be greatly increased. During the next half-millennium, it is probable that the expectancy of life at birth will rise to sixty-five years or thereabouts; but there is no likelihood that the streets will be cluttered with doddering creatures of a hundred and fifty summers, as so many people hope. An increase of fifteen years in the average length of human life will be hard enough to attain, and will bring to the fore a sufficient number of difficult sociological problems; an increase of double this amount would dislocate society completely. And, no matter how efficiently parasitism is controlled, there will be plenty of troublesome pathological conditions remaining. In fact, new diseases will develop as industrial and sociological changes occur. No amount of progress in pathology will prevent our internal organs from wearing out; so that if we escape gout and rheumatism and cirrhosis, we shall drop of heart disease after ten years of senile dementia, anyway. Nevertheless, our descendants can expect a reasonably long life which is relatively free from disability, which will be a good thing for the individual. They must also expect that many will be born who ought not to have been born, and that many will live to reproduce who ought to die —which will be a bad thing for the group.

We may also expect to have various and sundry pills invented which will overcome the ill effects of non-functioning organs. What insulin has done for diabetes, we may expect idiotin to do for feeble-mindedness. We shall have ostin for cleft palate, optin for color blindness, epileptin for epilepsy, and so on down the list. We shall thus have a period in which we save so many defectives that they may breed double and triple defectives; that the chief occupation of humanity will be dosing one another.

I am inclined to believe that these medical and chemical discoveries, coming thick and fast, will, indirectly, be the means of bringing the human race to see the essential soundness of eugenic philosophy. It will become absolutely necessary to call a halt on all blindly humanitarian impulses, and to adopt a wholly new policy. Such discoveries as I have just described will make it apparent to every one that natural selection can not be balked at every turn without serious consequences. They will make our descendants "eugeniconscious," as writers of advertising copy would say.

Again, we shall learn to synthesize

the various hormones. This advance, like all the others, will have both its advantages and its disadvantages. Much good will come from it when we learn how to supplement nature in a sensible way, a way that will bring about a fuller, happier life. But one foresees trouble ahead, with near-Methuselahs of both sexes ranting around in quest of a second dispensation of youth, until such time as they learn that the peace and quiet of a dignified old age has its favorable aspects.

Another change that is virtually certain to come is the control of reproduction in a strictly biological way. One may expect to see such methods perfected within the next half-century. There are several possibilities. I am inclined to think that the most practical will be the control of ovulation. If this device has any disagreeable psychological effects, then ways will be found for producing spermatoxins or for sterilizing the male temporarily.

One might continue to speculate thus almost indefinitely. And it is an amusing pastime which does no one any harm. Moreover, some such changes as we have outlined are certain to take place, though we can not describe them with any great precision. It is a pity that we can not return to see just what they are.

THE AGE OF THE EARTH—RADIOACTIVITY METHODS OF ITS DETERMINATION[1]

By Dr. ALOIS F. KOVARIK

DEPARTMENT OF PHYSICS, YALE UNIVERSITY

INTRODUCTION

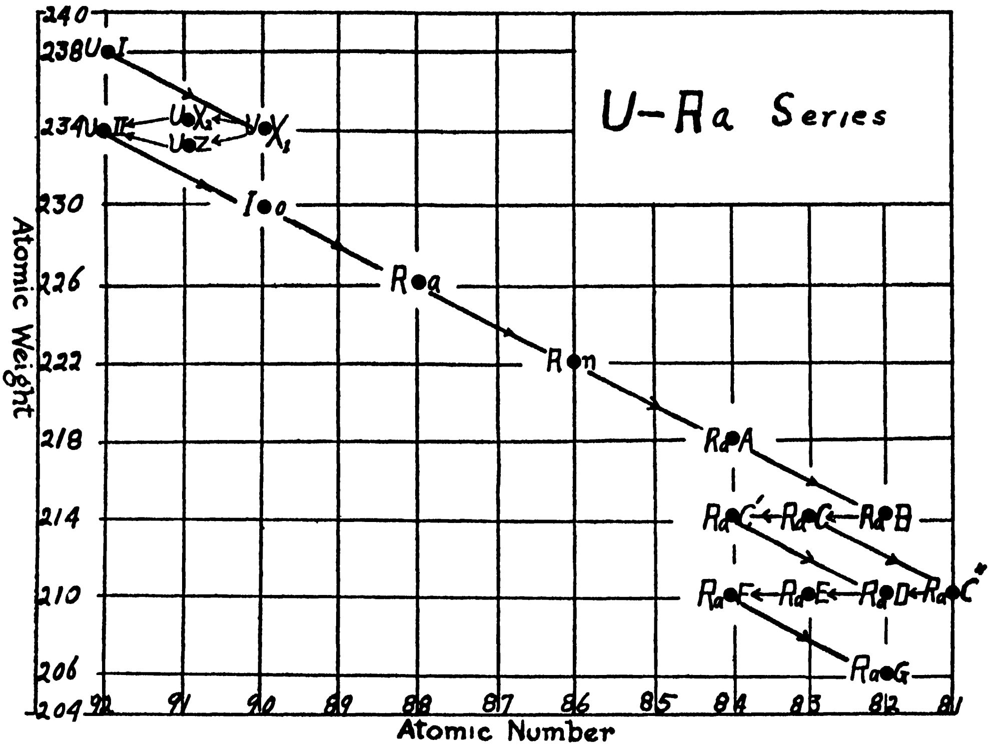
VARIOUS attempts have been made to estimate the age of the earth. We may refer to the methods used as astronomical, physical or geological depending upon the hypotheses and data involved. They are all useful scientifically in that we gain some basis of assurance that the underlying hypotheses may have some truth in them if by considering the same "age" they give reasonably concordant results. In the problem of the "age of the earth" it is essential that we have a clear conception of what the term "age" means in any particular case, otherwise apparently discordant results may lead one to condemn unjustifiably both the results and the methods, whereas the chief source of difficulty may be in the fact that measurements are made from very different starting points.

In the astronomical problem the age may mean the time that elapsed since the earth separated from the sun and this in turn involves the hypothesis that the earth did separate from the sun and the manner in which it may have happened. In the physical problem proposed by Kelvin it is the time that elapsed since the crust began to solidify and this involves the hypothesis of cooling. The data involved are the original temperature and the rate of cooling. Kelvin's handling of the problem left little to criticize in the method itself until we learned that radium is found in practically all materials of the earth's crust and that the rays emitted by radium produce heat when absorbed. It was then learned that the earth should be getting hotter instead of colder if radium were distributed throughout the earth in quantity averaging per unit mass the amount found as an average in the surface materials. Evidently, we are confronted with the necessity of greater experimental knowledge about the temperature, the pressure and the constitution of the interior of the earth in order to make this method really useful. In the geologists' problem the age is called by them geologic time, *i.e.*, the time that elapsed since the beginning of the oldest known formation. This age is subdivided into various subdivisions and it is of great interest to the geologist to get the lengths of these subdivisions in years. The geologists for more than a century have followed a sound principle in estimating this age, namely, by studying the extent of the existing formations and the rate of production (and also destruction) of similar rocks as the process is going on to-day. There are many difficulties encountered in these studies and the probable error is quite great; nevertheless, when all things are considered the order of magnitude of the age obtained should be correct.

RADIOACTIVITY

Confining our problem to the limits set up by the geologist we may hope to

[1] At the request of the editor the author prepared this popular presentation of the radioactivity methods. It is based on a part of his work which was the outcome of cooperative work of the subcommittee of the National Research Council. This committee has now in the course of publication a bulletin entitled "The Age of the Earth" and contains parts written by the individual members. The committee are Ernest W. Brown, Arthur Holmes, Alois F. Kovarik, A. C. Lane, Charles Schuchert, and Adolf Knopf, *chairman*.



get a reasonable answer to our question about the age of a geological formation by studying the radioactive minerals in such a formation. We shall see that one of the radioactivity methods presents a great probability of success in estimating the age of the formation by deducing the age of a primary radioactive mineral from the formation. A radioactive mineral is so called because it contains radioactive substances. A radioactive element, *e.g.*, radium, is an element whose atoms disintegrate and change into atoms of another element and the disintegration of the atom is accompanied by emission of a radiation from the disintegrating atom: either (1) an alpha ray which has been proven to be the nucleus of a helium atom or (2) a beta ray which has been proven to be an electron and either of these radiations may be accompanied by a third radiation, an electromagnetic radiation, called the gamma ray. The emission of the alpha ray or of the beta ray constitutes the basic change in the constitution of the nucleus of the atom so that when the remaining material parts and energies are rearranged to be in equilibrium we have a new atom lighter in weight and of a new nuclear constitution and possessing new chemical properties. This phenomenon of disintegration noticed in the case of these elements is called the radioactivity of the element and the branch of science embracing these and related phenomena bears the name of radioactivity.

The fundamental quantitative law of radioactivity may be stated as follows: the rate of disintegration depends on the number of atoms and on the nature of the radioactive element and the ratio of the number of atoms disintegrating per second to the number of atoms of the radioactive element equals a constant which constant is different for each radioactive element and, therefore, char-

acterizes the radioactive element. These constants are known for the various radioactive elements. In symbols the law may be given as follows:

$$\frac{\frac{dN}{dt}}{N} = -\lambda$$

where $\frac{dN}{dt}$ represents the number of atoms disintegrating per second; N, the number of atoms; λ, the characteristic disintegration constant of the particular radioactive element under consideration and the minus sign indicates that N decreases in value with time. If N_0 is the number of atoms at the beginning and N the number after some time t, then by integrating the above expression we get a relation between N and N_0 as follows:

$$N = N_0 \varepsilon^{-\lambda t}$$

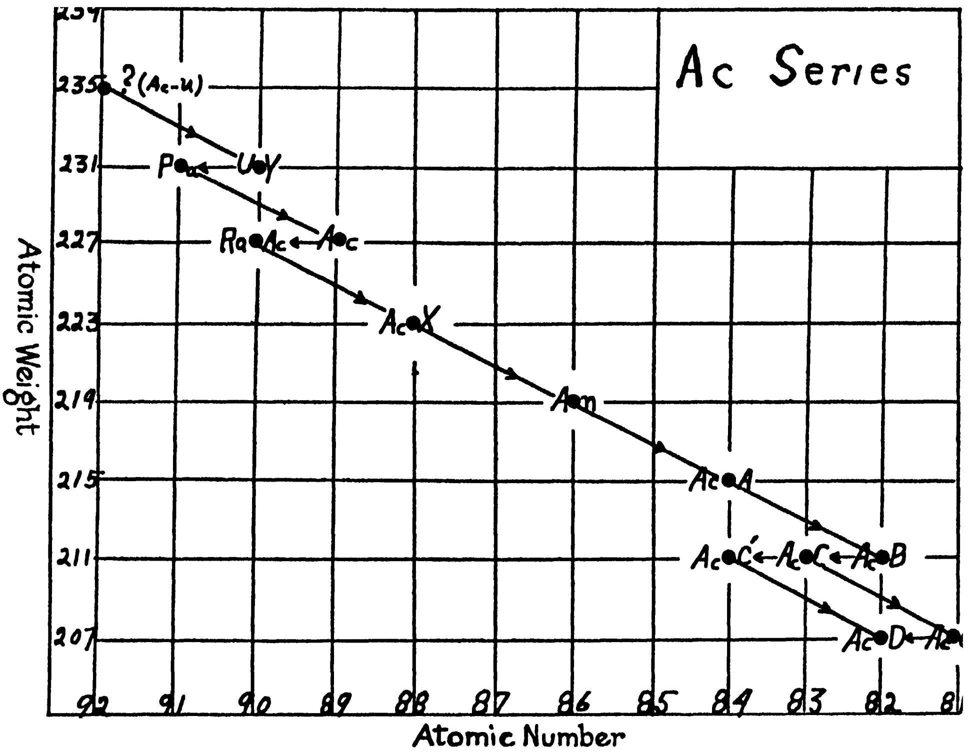
where ε is the base of the Naperian (or natural) logarithms. This relation connects the amounts of a radioactive substance at the beginning and at the end of an interval of time. We see, therefore, that the phenomenon of disintegration of a radioactive element furnishes us, so to speak, a clock by means of which time can be measured. We shall later refer to this matter.

An atom which has disintegrated leaves behind matter and internal energy which, after rearrangement of its parts, becomes the new atom. This new atom may likewise be radioactive and it is found by studying all the radioactive elements known that they can be arranged into three series, called the uranium-radium series, the actinium series and the thorium series. The head of the uranium-radium series is uranium I, of the actinium series it is actino-uranium, and of the thorium series it is thorium. Every radioactive atom within any one of these three series is formed from the atom preceding it in the series and it follows, therefore, that when one atom of the head of a series disintegrates there will be formed in due time one atom of every one of the radioactive elements of that series and that ultimately one atom will be formed of that product into which the last radioactive element of the series disintegrates. In the uranium-radium series the last radioactive element of the series is polonium, and its atoms disintegrate into atoms of a non-radioactive element called radium G. The ultimate non-radioactive element of the thorium series is called thorium D and of the actinium series, actinium D. The non-radioactive end products of the three series are all isotopes of ordinary lead.

Isotopy and Atomic Structure

It seems expedient to digress a little more at this time and make clear the meaning of isotopes, inasmuch as the method to be described as the best radioactivity method for the determination of the age of a radioactive mineral demands a knowledge of the isotopes of lead. Mendeléeff arranged the known chemical elements in a periodic system according to the chemical properties of the elements. There was one element for each place (excepting those places for which elements had not been discovered). When Boltwood announced the discovery of ionium, the radioactive element whose atoms after disintegration form atoms of radium, he also announced the important fact that ionium and thorium have exactly the same chemical properties and that he could not separate them from each other by any known *chemical* means, *i.e.*, ionium and thorium, once mixed, were found to be chemically inseparable.

This work of Boltwood indicating two elements in the same place in Mendeléeff's table formed the basis of much further investigation by chemists and physicists bringing forth other discover-



ies of a similar character and ultimately leading to the establishment of the new branch of science, called Isotopy, which is so important in to-day's physical and chemical researches. The word *isotope* was coined by Soddy, who contributed much to the subject, and is derived from two Greek words *isos* and *topos,* meaning same place, and designates elements which have the same chemical properties and occupy the *same* place in the periodic table.

The researches in other fields, particularly in the study of the Röntgen rays and the scattering of alpha rays by the atoms of various elements, have brought forth very important results bearing on the structure of the atom and on the position of the elements in the periodic table. We can not go into these researches here but a few of the conclusions from them should be noted in order to understand the diagrams given for the radioactive elements.

The first general conclusion concerns the general structure of any atom. It is due to Rutherford and to Bohr. Any atom has a central portion called the nucleus which possesses nearly the whole mass of the atom, which is very small compared to the size of the atom and which is electrically charged positively. Outside the nucleus are the negative electrons, as many in number as are necessary to equal the positive charge of the nucleus to make the atom neutral, moving in some kind of orbits and are located in definite "energy levels." If an electron has left its particular energy level, for any reason whatever, and some other electron from outside the atom or from some energy level outside of the one in which there is a "vacancy," then during this transition of the second electron, and due to it, a radiation of visible or invisible light is emitted by the atom and its wave-length is a definite one and depends on the amount of

the change of the energy levels. This forms the basis for the modern theoretical spectroscopy. The electrons in the part of the atom outside the nucleus are also responsible for the "valency" of the elements in chemical combinations.

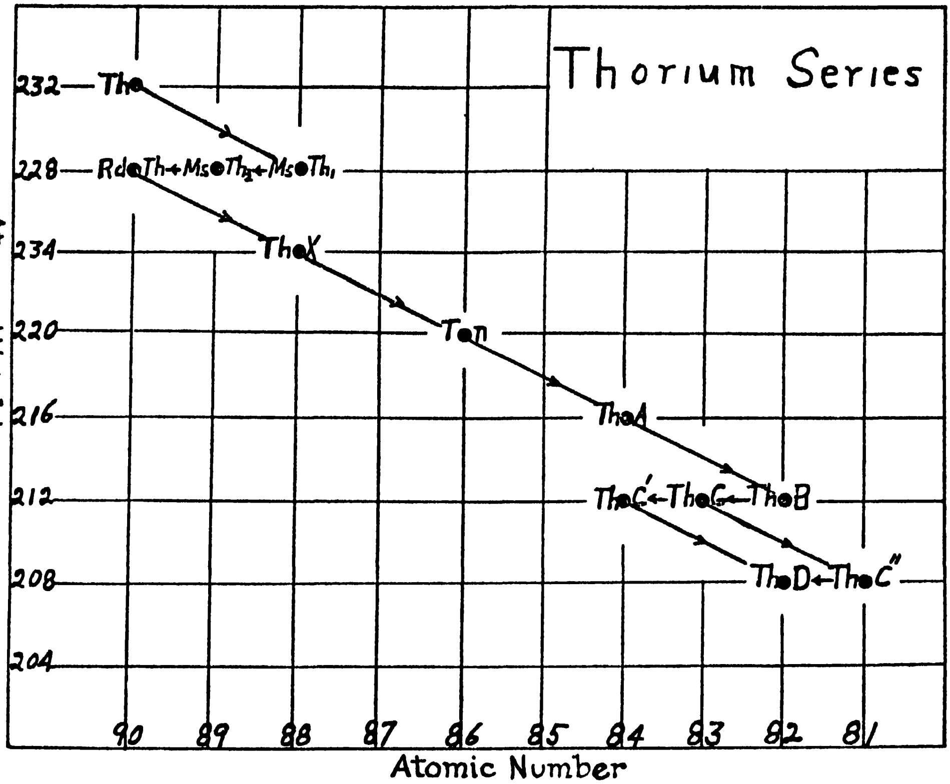
Later the work of Moseley on characteristic x-rays of various elements and that of Chadwick on the scattering of alpha particles by atoms of copper, silver and platinum showed a connection between the charge of the nucleus and the position of the element in the periodic table. If we take the electron (positive or negative) as the unit of charge of electricity, then this relation is that the number of the electron units of charge of the nucleus is the number of the position of the element in the periodic table, *i.e.*, if e represents the charge of electricity, properly called the electron, 1e, 2e, 3e, ---- 29e, ---- 92e are the respective charges of the nuclei of hydrogen, helium, lithium, --- copper, ---- uranium and the numbers 1, 2, 3, -- 29, -- 92 represent the positions of these elements in the periodic table in which they are arranged according to their chemical properties, beginning with the lightest, the hydrogen atom and proceeding to the heaviest, the uranium atom. The numbers, 1 to 92, are called the atomic numbers. Incidentally, these numbers also give us the number of (negative) electrons in the part of the atom which is outside the nucleus.

The second important fact which we must note is the Displacement Law and this concerns the positions of the radioactive elements in the periodic table. The law is due to Soddy and to Fajans. It was obtained by studying the chemical properties of radioactive elements and placing the elements in the periodic table. It was then found that after the disintegration the new atom which was formed occupied a place in the periodic table whose atomic number was smaller by two or larger by one than that of the disintegrating radioactive atom, depending upon the fact whether an alpha ray or a beta ray was emitted. On the present knowledge of the atomic structure, this is comprehended when we bear in mind that if the alpha ray leaves a nucleus, the positive charge of the nucleus is made smaller by plus 2, namely the double positive charge of an alpha particle, and if the beta ray (electron) leaves the nucleus, the positive charge of the nucleus is made smaller by minus 1, namely the negative single charge of an electron, *i.e.*, it becomes more positively charged by one unit. Hence, the atomic number in the former case is two less than that of the disintegrating atom and in the latter case it is one more. Since the atomic number is also the number of the element in the table it explains the position of the new radioactive element formed after disintegration.

The atomic weight of the new atom is less by the loss by radiation and this is approximately 4 units less when an alpha ray is emitted and is negligibly less (electron's mass being small) when a beta ray is emitted. These considerations will help in understanding the charts giving the atomic numbers and atomic weights which are given only as whole numbers.

It will be noticed that the end products—the non-radioactive elements—of the three series, radium G, actinium D and thorium D, respectively, are all of atomic number 82 which is also the atomic number of ordinary lead. They are the isotopes of ordinary lead. Their atomic weights are, respectively, 206, 207 and 208, while that of the ordinary lead is 207.2.

It is to be noted, therefore, that the chemical processes which separate ordinary lead from the mineral will simultaneously separate all these isotopes, if present, with the ordinary lead and the



lead so obtained will be a "mixture" of all of them with an atomic weight depending on the amounts and the atomic weights of the various constituents.

Radioactive Methods of Calculating the Age

The Helium Method: There are three proposed radioactive methods of determining the age. The oldest is referred to as the helium method. It was first proposed by Sir Ernest Rutherford, in 1904, in an address before the International Congress of Arts and Sciences in St. Louis. Helium is found in every radioactive mineral, in fact terrestrial helium was discovered in such a mineral. It is the result of the accumulation of alpha particles emitted by the various alpha ray emitting radioactive elements present in the mineral, and each of these alpha particles is the nucleus of a helium atom and on capturing a couple of electrons becomes a helium atom. It is evident that if we know the amounts of alpha ray emitting elements present and also their disintegration constants and the total amount of helium in the mineral, we can calculate the time it took to accumulate this amount of helium. However, helium being a gas, there is a great probability of loss by leakage, and the calculated time can, therefore, represent only a "minimum" age of the mineral. It may be of interest to note that the Berlin physical chemist, Paneth, recently applied this method in studying meteorites. The age he deduced for these extraterrestrial visitors to our earth is of the order of 2 to 3 billion years.

Pleochroic Halo Method: Another radioactivity method is based on the coloration of pleochroic halos found, for example, in biotite and fluorspar. It is due to Joly and Rutherford. It has

been shown that in general the radii of the halos correspond to the ranges of the alpha particles from the radioactive substances imprisoned with the central inclusion, which is generally zircon. The coloration is an effect of ionization by the alpha particles. If we irradiate the same material which contains the halos, *e.g.*, mica, with alpha particles from a known strong source and allow this to go on until the same shade of color is produced in the mica as is found in the halo, then the product of the number of alpha particles incident and the time of irradiation will equal the product of the much smaller number of alpha particles emitted from the inclusion in the halo and the geological (long) time to form the halo. The geological time can be obtained if we can estimate the strength of the radioactive element in the halo, provided, also, no other agent alters the coloration during the geological time. The fact is that it has been shown by experiments that both heat and prolonged ionization can alter the color—even producing "bleaching." Furthermore, the amount of radioactive material in the inclusion can not be accurately determined. Consequently, the method is not accurate nor dependable for age determinations.

Boltwood's Lead Content Method: The third method is one which offers the greatest promise of success. It is due to Boltwood.[2] Boltwood discovered, in 1907, the radioactive element *ionium,* the parent of radium, in his attempts to find proof of the disintegration theory of Rutherford and Soddy (advanced in 1903). He also gave attention to the ultimate disintegration products of the uranium-radium series and observed that all minerals containing uranium also contained lead, and came to the conclusion that lead was the final disintegration product of uranium. This was the first time that the idea was advanced that the final disintegration product of the uranium-radium series is lead. He found, however, that the amount of lead per gram of uranium in the mineral varied in different minerals. He arranged the minerals according to the lead-to-uranium content and drew attention to the fact that the increasing value of the ratio corresponded to the increasing age of the geological formation in which the mineral was found. To get this "age" expressible in years he assumed all of the lead to be the result of the disintegration of uranium. Knowing the rate of disintegration of a known amount of uranium, the rate of formation of the lead becomes known, and the age can be obtained.

In order to understand the process of reasoning that Boltwood followed—and this is necessary if we are to understand the complete method given below—let us assume a primary mineral containing originally only uranium as a radioactive substance. Let it be understood that no alteration of the mineral has taken place, except such alteration as is due to radioactive changes. The chemical analysis of such a mineral will give us the present amount of uranium in it and also the amount of lead per given amount of the mineral (generally expressed per 100 grams mineral) Knowing the present amount of uranium and the disintegration constant of uranium we could calculate the original amount of uranium if we knew the time elapsed, *i.e.*, the age of the mineral—or we can express the number of uranium atoms which disintegrated during that time in terms of the time by using the equations given above. Now, every atom of uranium which disintegrates becomes ultimately an atom of the end product, radium G. If this end product is the lead found—as Boltwood sup-

[2] Bertram Borden Boltwood (1870–1927), professor of radio-chemistry, Yale University. See memoir in *American Journal of Science,* 1928, or forthcoming memoir of the National Academy of Sciences.

posed—we can tell from its amount the number of its atoms and this number must be equal to the number of uranium atoms which disintegrated. Hence we can put the number of atoms of lead equal to the expression giving us the number of uranium atoms disintegrated —an expression involving the known amount of uranium found, the known disintegration constant and the *unknown time* during which the disintegration took place. This equation can be solved for the time. This is correct and would be sufficient were it not for the fact that every radioactive mineral contains radioactive elements of all the three series, and may have contained originally (and therefore also at the time of the analysis) ordinary lead for the same reason that it contained uranium. That end products of the three series are isotopes of lead was shown by Richards, Hönigschmid and other noted chemists.

Complete Solution

It is, therefore, evident that Boltwood's simple calculations of the age of the mineral must be modified to take into account the above-mentioned facts. The importance of taking thorium and its end product into consideration was soon realized because a vast number of uranium-bearing minerals contain also an important amount of thorium. Regarding actinium we knew too little of its real origin until about a year ago, but it now seems certain that the actinium series originates in an isotope of uranium, called actino-uranium, and that its end product is of an atomic weight 207, whereas radium G is 206, thorium D, 208, and ordinary lead, 207.2. Most of the calculations made, heretofore, ignored the presence of ordinary lead and disregarded actinium D, with the result that some confusion has been brought about. It is certain that the pitchblende from Jachymov (Joachimsthal, Czechoslovakia)—the mineral in which Madame Curie discovered radium—may contain ordinary lead because ordinary lead occurs in the same veins from which the pitchblende is obtained. If this is true of a particular pitchblende, why should we assume that it may not be true of other pitchblendes, except as to the amount of the ordinary lead?

With regard to actinium D it was supposed to be only 3 per cent. of radium G since actinium to uranium ratio in some minerals, accurately determined, show this ratio and actinium was supposed to branch off the uranium and, therefore, actinium D and radium G would be formed at these relative rates. Since the recent evidence points to the origin of the actinium series from an independent isotope of uranium, actino-uranium, whose disintegration is much more rapid than that of uranium, it is evident that the amount of actinium D, compared with the amount of radium G, may be much greater than 3 per cent. and will be greater the older the mineral. For these reasons the formulation of the basic equations which will give us the time, *i.e.*, the age of the mineral, must take regard of the possible presence of ordinary lead as well as of actinium D.

The basis for the formulation of the necessary equations is given in words by stating the following three fundamental facts:[3]

I. The sum of the masses of radium G (atomic weight, 206), actinium D (atomic weight, 207), thorium D (atomic weight, 208) and ordinary lead (atomic weight, 207.20) equals the mass of lead of atomic weight, A, found in the mineral.

II. The sum of the number of atoms of radium G, actinium D, thorium D and ordinary lead equals the number of

[3] A. F. Kovarik, "Basis for the Calculation of the Age of Radioactive Minerals," *Am. J. Sci.* [5] 20: 81–100 (1930).

atoms of lead of atomic weight, A, found in the mineral.

III. The number of atoms of the parent substance, disintegrating in each of the above cases, results ultimately in the *same* number of atoms of the end product, which is an isotope of lead.

These three statements can be put into the form of algebraical equations. The third statement will give the number of atoms (or mass, if desired) of the end product in terms of the number of atoms (or mass) of the parent substance found in the analysis and in terms of the time. It is in the equations derived from this statement that "time" enters into all of our equations and into the final formula. It is here that the "radioactivity clock" measures the time during which the observed changes of uranium atoms into radium G atoms, of actino-uranium atoms into actinium D atoms and of thorium atoms into thorium D atoms take place, and these changes are put into a quantitative form by the first two statements. The parent substances are uranium, thorium and actino-uranium. The first two can be readily determined by the chemical analysis of the mineral; the actino-uranium, being an isotope of uranium, presents difficulties of direct determination but can be determined indirectly by measuring the ratio of the amount of actinium (which would be in a radioactive equilibrium with the actino-uranium) to that of uranium.

Consequently, when a proper primary mineral is chemically analyzed and for a known amount of the mineral the amounts of uranium, thorium and lead are determined and in addition the atomic weight of the lead and the ratio of the actinium to uranium are also determined, then with the further knowledge of the atomic weights and the disintegration constants of the radioactive elements, our equations make it possible to obtain time, the age of the mineral, and also the amount of ordinary lead.

It may be surprising to learn that although age calculations have been going on for twenty years, yet there is not a single case of a mineral for which we have a complete set of data. We have many giving us the relative amounts of uranium, thorium and lead but no atomic weight of the lead. We have a certain number of excellent analyses which include the atomic weight determination but which lack the actinium to uranium ratio;[4] while those giving excellent determinations of this ratio lack all the rest of the data. It would seem, therefore, that while we have the means of obtaining an answer to our problem, we lack some of the data necessary for a complete solution. It is evident, therefore, that further work on the analyses is necessary and that these analyses should be made on the same specimen and a complete set of data should be obtained. However, we can circumvent the difficulty and obtain a fairly accurate determination of the time and yet take into account the possible presence of ordinary lead and reasonably accurately also account for the actinium D. This can be done since the atomic weight of actinium D is nearly the same as that of ordinary lead. It is done by considering the actinium series as if it were a branch off the uranium radium series--as was supposed to be the case until very recently. In this case the term involving radium G will involve a part of actinium D and the term involving ordinary lead will involve the rest of the actinium D, except for the error brought about in the number of atoms (atomic weight, 207.2) used instead of some other number of atoms (atomic weight, 207). Because

[4] A. F. Kovarik, "Actino-uranium and the Actinium to Uranium Ratio," *Science* 72: 122–125 (1930).

the amount of actinium D is not nearly so large as radium G, the error so introduced is not large. The equations set up for this case will involve only such data as we possess at the present time. The formulae can be put into practical form for numerical solutions. Applied to the two oldest minerals, namely, a uraninite from Keystone, South Dakota, and to a uraninite from Sinyaya Pala, Carelia, U. S. S. R., we obtained, respectively, 1,465 million years and 1,852 million years for the ages of these two minerals. Various uranium-bearing minerals from Norway give values ranging from 825 to 986 million years. It may be needless to add that when we have a complete set of data the equations derived from the above three statements of facts furnish the correct solution of the problem of the age of the mineral. The 1,852 million years represent a minimum measure of the age of the earth. The ages of the other minerals are, of course, in no conflict with this value because they represent the ages of respective formations which are geologically younger.

WHAT IS NEW IN MATHEMATICS?[1]

By Professor EDWARD V. HUNTINGTON

HARVARD UNIVERSITY

To ask "What is new in mathematics?" may seem to many of you like a foolish question. How can there be anything new in mathematics? How can two plus two be anything else than four? How can there be any new changes in so old a subject as mathematics?

Well, in one sense mathematics does not change. Whatever is once established as a mathematical truth is true for all time. The Pythagorean theorem about the square on the hypotenuse of a right triangle is just as true to-day as it was in the days of Pythagoras, twenty-five centuries ago, and it will remain equally true twenty-five centuries hence. Once true, always true, in mathematics; and in that sense, mathematics does not change.

But in another sense mathematics is changing enormously and with astonishing rapidity. New mathematical truths are discovered every year. The old truths are not discarded, but whole new branches of mathematics are constantly being developed. Mathematics is no longer a single science, but rather a great collection of sciences, so vast in extent that no one man can hope to master more than a small fraction of the field. The growth has been so rapid that even expert mathematicians working in different branches may be entirely ignorant of other mathematicians' results. No science is expanding more rapidly in the modern world than the old, old science of mathematics.

When the present president of Harvard University was a student in college he could take, and did take, every course that was offered in mathematics, on top of all the regular courses required for a general education. To-day, the mathematical courses offered at this one university would take seven or eight years of continuous work to complete, and even all these courses would give merely an introduction to the vast realm of mathematical knowledge. In every civilized country flourishing mathematical societies, whose total membership runs into tens of thousands, are actively pursuing the newest developments in advanced mathematics, and scores of mathematical journals are devoting themselves exclusively to the publication of these new discoveries.

A few decades ago, the high water mark of a university course in mathematics was the differential and integral calculus, and only a few exceptional students ever dared to rise to such dizzy heights. To-day the calculus is merely the starting point in college mathematics. In Harvard University alone over 500 students elect a course in calculus every year—most of them in their freshman year. In the country at large there are probably half a million people who have studied the calculus, and half a million more who appreciate how valuable a knowledge of the calculus would be to them if they had it.

What a change this is over a century ago! Mathematics is no longer regarded as hopelessly difficult; and students who specialize in mathematics—even in its higher branches—are no longer regarded as hopelessly "queer." What is the reason for this change? A large and increasing number of people have discovered two things about higher mathematics; first, that it is useful, and, second, that it is beautiful. When any branch of study is found to be useful and beautiful, it is bound to become popular.

[1] A radio talk presented under the auspices of The National Research Council.

First, mathematics is useful.

Of course as far as the elementary branches are concerned, the usefulness of mathematics has long been admitted. Every one who makes out an income-tax return recognizes the necessity for a little knowledge of arithmetic. Also elementary geometry and trigonometry have long been recognized as useful tools for the designer, the surveyor and the navigator.

But in regard to the higher branches of mathematics, it is only in comparatively recent times that their usefulness has been appreciated.

The extraordinary development of engineering in the present century has called for a wide-spread use not only of the calculus, but also of higher branches, such as the theory of functions of a complex variable, the theory of differential equations, and the extremely modern theory of integral equations, all of which had been originally developed without the slightest idea of their use in technology.

The famous electrical engineer, Charles P. Steinmetz, was twenty years ahead of his time in urging the need for more and higher mathematics in engineering; to-day, the growing importance of higher mathematical training for researchers and designers in engineering is constantly emphasized by the leaders of the great industrial corporations. Pick up any recent volume of the *Transactions* of the American Institute of Electrical Engineers, for example, and note the great mass of mathematical symbols that appear on almost every page. Mathematics pays, in dollars and cents.

In modern physics, there is so much mathematics of a very advanced character that it is hard to draw the line between what is physics and what is mathematics. For example, the Einstein theory of relativity is essentially a combination of non-Euclidean geometry and tensor analysis, both of which are branches of pure mathematics.

Without the results of mathematical physics, which is mostly mathematics, our present-day, long-distance communication signals would be impossible. You all know how the first long-distance submarine cable was a failure because of faulty design, and how Lord Kelvin improved the design and made the cable a success. He was able to predict the success of his design on the basis of purely mathematical computations. These computations were in fact so mathematical that the engineers at that time could scarcely believe the result, until they actually saw it work.

Again, in the field of long-distance telephony, mathematics has led the way to inventions which have greatly increased the distance the voice can be carried over a wire of given size. If it were not for mathematics, you could not send a long-distance telephone message to-day. And as everybody knows, the development of the radio itself, to which you are now listening, has been directly dependent on mathematical-physical researches of the most advanced sort. A recent text-book on radio makes the significant remark that the more easily the student can think mathematically, the greater are the possibilities ahead of him, in the science of radio.

Moreover, chemistry, biology, geology and even economics are coming more and more to realize that the rate of progress in these fields, under modern conditions, is directly proportional to the amount of mathematics that they use. A very brilliant medical man, whom this and other countries delight to honor, told me the other day that it is quite impossible for any one to keep up with recent developments in physiology without a much more extended knowledge of higher mathematics than it was possible to obtain when he was in college.

Even in the world of business and finance, the most recent mathematical theories on the analysis of statistical

data are proving to be indispensable to progress. For example, the successful installation of the dial system in telephone exchanges would have been impossible without the application of the most recent advances in the theory of probability. Stock-market forecasting is another field in which more and more mathematical theory is being applied. The mathematician of the future, instead of solving silly puzzles about "how old is Ann," may be using higher mathematical equations to figure out the next swing of the market!

The first reason, then, for the changed attitude toward higher mathematics is the enormous extension of its usefulness in practical human affairs

The second reason for the new popularity of mathematics is more vital and more powerful. Mathematics is not only useful; it is also extremely beautiful The beauty of a mathematical result is the fundamental motive for its pursuit. Every creative mathematician is essentially a creative artist. The most important and fertile discoveries in the whole field of mathematics have been made by men who were guided by esthetic motives—men whose insight into unsuspected relations between apparently diverse phenomena led them to replace an ugly and unsatisfactory chaos by a beautiful and illuminating order.

That is the great secret of mathematics—its power to reduce the complex to the simple. Every branch of higher mathematics enables us to survey, as one simple whole, a vast number of seemingly complicated and unrelated facts. Mathematical notation appears complicated only because it is really so simple. A single symbol expresses the end result of a long series of processes. The thing that is too complicated for the mind to grasp as a whole is the series of processes; the thing that is simple to understand and manipulate is the single symbol.

For example, the Arabic numerals, including zero, are the indispensable basis of all modern science. Imagine trying to multiply 3,142 by 5½ per cent. in Roman numerals! Imagine a telephone directory with 1928 spelled out as MDCCCCXXVIII! Again the symbol for a definite integral, which used to strike terror to the uninitiated, is now viewed with a friendly eye, as one of the most beautiful simplifications that mathematics has ever invented. It takes artistic insight to pick out the really important concepts; and it takes artistic genius to devise a fitting notation for them The result, when successful, is beautiful in the most satisfying sense. Beauty, I say—beauty of clearly thought-out logic, of simplicity of form —is the impelling motive and the ultimate goal of higher mathematics.

In the Chicago World's Fair, in 1933, which will exhibit in a new and striking way a century of progress in all the sciences, the old-new science of mathematics will occupy the central position. It is hoped that through that great exposition the general public, to some of whom I am now speaking, may gain a vivid picture of the beauty, as well as the utility, of the stupendous new discoveries in higher mathematics. Not every one can be a technical mathematician, just as not every one can be a technical musician; but every one can and should have some appreciation of the value of the mathematical method of thinking, just as every one can and should have an appreciation of good music. The mathematical method of thinking is the only logical method. In these days of newspaper headlines and frantic propaganda, the habit of disinterested, logical thinking is a vital necessity to all of us. What is new in mathematics is the new and growing appreciation of the fact that the study of mathematics in its eternal beauty and its ever-expanding scope is the best possible stimulus to this vital habit of disinterested, logical thinking.

PLANT HUNTING IN MADAGASCAR[1]

By Dr. CHARLES F. SWINGLE

UNITED STATES DEPARTMENT OF AGRICULTURE

THE desert, silent and uncompromising, lay ahead of us. Natives and whites thereabouts tersely called it "the brush." This was not a waste of drifting sand, but a tangled expanse of almost impenetrable desert growth. Many of the plants were queer and distorted, defiant of Nature's parsimonies, and resistant to them. Substantial bottle trees 10 feet thick, Euphorbias 40 feet tall, gigantic didiereas with their long leafless branches growing into the wind, wonderful aloes, kalanchoes and other flowering shrubs growing where droughts may last half a dozen years, but seemed to emphasize the uniqueness of this region. To the two botanists who paused here on the verge of this "promised land" the very grotesqueness of the plants suggested sinister allurement.

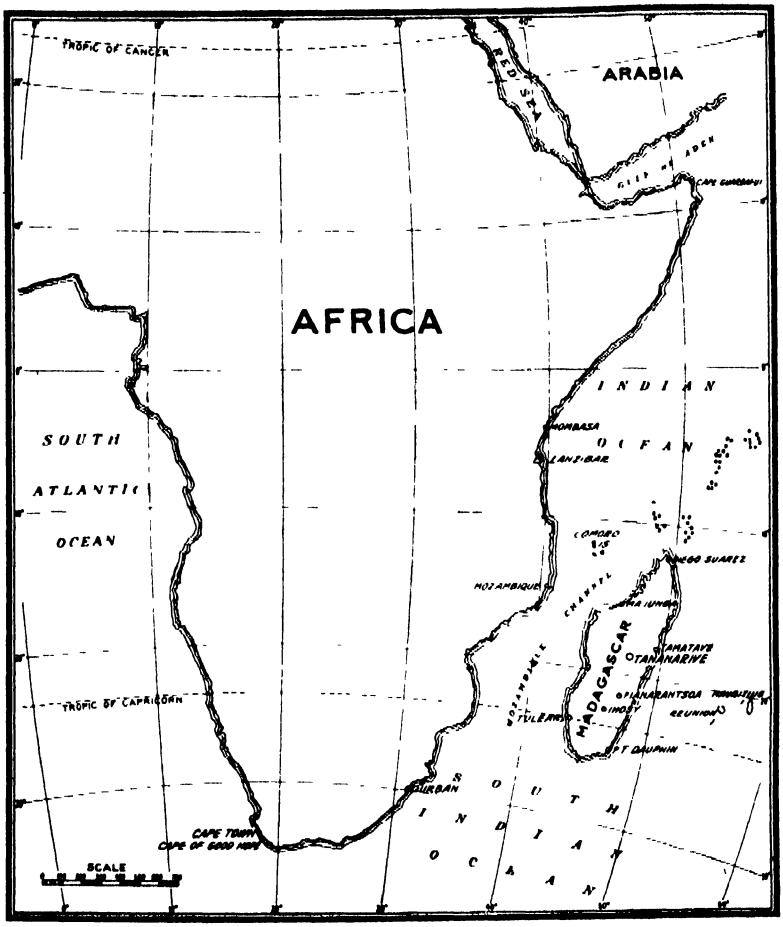
Much of southwestern Madagascar had never before been visited by plant collectors. It was my good fortune to be the first American botanist to visit any part of the island. It was rare adventure to be half a world away from home, on the trail of living plants. Especially did I hope to find *Euphorbia intisy*, an almost extinct rubber plant. Botanists best acquainted with the island feared it was gone. Even my companion, Dr. Humbert, of the University of Algiers, a veteran of two previous expeditions to Madagascar, was very dubious as to its survival. But so unique was this species, and of such promise to our arid Southwest, I could not easily relinquish hope of discovering at least a few specimens while our expedition was collecting plants in the region where intisy had formerly been so abundant.

I knew that nine tenths of all the rubber produced in the world to-day was derived from a few seeds shipped out of Brazil some 50 years ago, and that a few specimens of intisy from Madagascar might mean a real contribution to American agriculture in years to come.

It had been an arduous trip to reach the rim of the desert in the lower part of the island. Our southward journey through the interior of Madagascar is comparable in actual miles to a trip from Boston by a roundabout route to Savannah, Georgia. It had begun with an unforgetable boat ride up the Betsiboka River. We had stepped from our rickshaws at the dock in Majunga, on the northwest coast, that July morning to see a hustling gesturing crowd ready to embark with us. Our zest for the river trip departed with the first glimpse of the *Lazzarri*, a frail craft not more than 35 feet long. At least forty men and women of all colors and ages were ready to accompany us in this miniature wood-burning steamer on a treacherous inland river! We had a Malagash crew—a pilot, a fireman, a cook-waiter-barman, and a captain. From the suspiciously light color of the latter, and from his swagger and pomp, one could not but surmise that in this captain's veins was flowing the blood of old American sailors— either of the *slavers*, or the later and more numerous *whalers* who came from New England to this far-away coast.

Getting aboard the *Lazzarri* was a serious affair. Hoisted to the iron deck from the shoulders of a native who had

[1] With photographs by the author and Professor Henri Humbert.

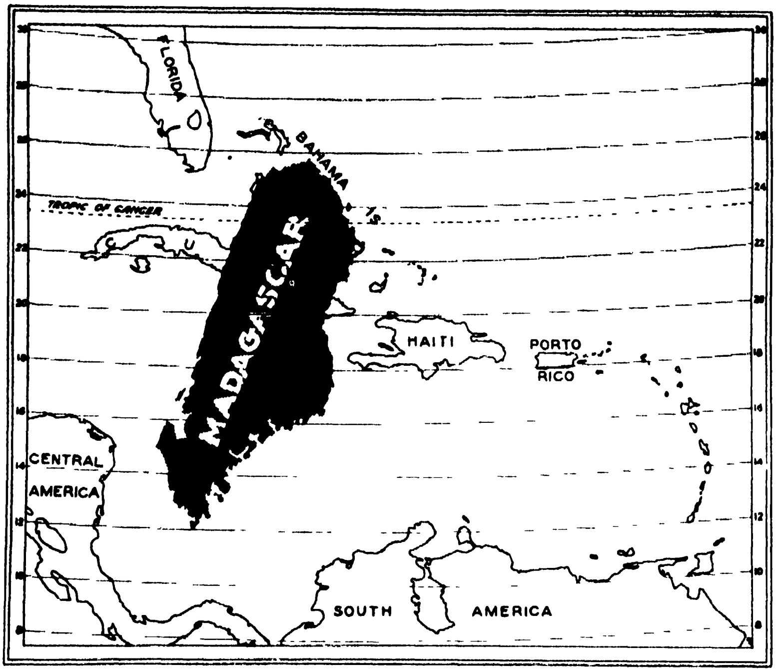


MAP SHOWING THE LOCATION OF MADAGASCAR, FRANCE'S "GREAT AFRICAN ISLAND"

ALTHOUGH MADAGASCAR LIES BUT 240 MILES OFF THE EAST COAST OF AFRICA, IT HAS DERIVED MOST OF ITS HUMAN INHABITANTS, AS WELL AS A LARGE PROPORTION OF ITS ANIMAL AND PLANT LIFE, FROM THE EAST INDIES, MORE THAN 3,000 MILES DISTANT.

waded out bearing me on his back, I called attention to my arrival by sprawling upon the muddy floor. Not only once did American dignity lie its length, measured on the slippery deck, but three times, before I could lurch to a camp chair to regain my breath and poise.

At first the discomfort of being cramped and crowded was somewhat mollified by my interest in the new country. The brick-red waters of the Betsiboka contrasted strangely with the cool green of the mangrove which lined its banks. Gradually mangrove gave way to spreading palms. These beauties of the tropics laid their dark fans against the sky in a series of unforgetable twilight pictures as we slipped by island after island. Gorgeously colored birds flitted in and out among them. Madagascar is within easy flying distance of the African coast and its bird life is largely, though by no means entirely, that of the great continent nearby. Brilliant parrakeets, snowy aigrets, and queer ibis—the bird depicted by the



NOT SUCH A LITTLE ISLAND AFTER ALL

MADAGASCAR IS APPROXIMATELY THREE TIMES AS LARGE AS ALL THE WEST INDIES COMBINED, AND STRETCHES FROM 12° TO 25.5° LATITUDE (SOUTH).

ancient Egyptians in their hieroglyphics—darted here and there.

Just before dusk our boat drew alongside the shore, and although there was no indication of a village there, thirty additional passengers appeared from somewhere and squeezed aboard. Up to this time the boat was overcrowded; after this it was almost unendurable. Certain it is, in no other country of which I know, would such jamming have been accepted so good naturedly. It was only the extreme affability of the Malagash which made this really dangerous doubling of our human cargo possible.

Early in my observation of the natives I had been impressed by their easygoing, carefree ways. At a stop on one of the Comoro Islands, since our boat was unable to approach the shore closely the town had taken to boats and come out to greet us, jabbering of pineapples, coconuts, sugar cane, and bananas for sale. In the confusion, two port police were accidentally shoved overboard into the sea! Nothing more than heated words ensued, which in the end gave way to hearty peals of laughter. Where else, but in nonchalant Madagascar, could the dignity of the law have been spilled into the brine, without vengeful consequences?

Bedtime preparations on the boat were simple. From the depths of the boat was dug up a dirty mattress. The dining table was covered with it, a sheet spread, and the most distinguished member of the passenger list—an important colonial official—escorted to it. Dr. Humbert accepted similar accommodations on one of the two benches, but I declined the other bench as graciously as possible thinking a night on my camp chair preferable. Almost immediately, however, I heard the buzz of mosquitoes.

These called for prompt work. I could not afford to neglect their warning, for it was in this region that thousands of French soldiers had died of malaria during the French conquest of the island about 30 years before. One of Madagascar's early kings had bragged that he had a commander, General Tazo (fever), who could never be defeated. As yet he never has been, so I made for my mosquito net.

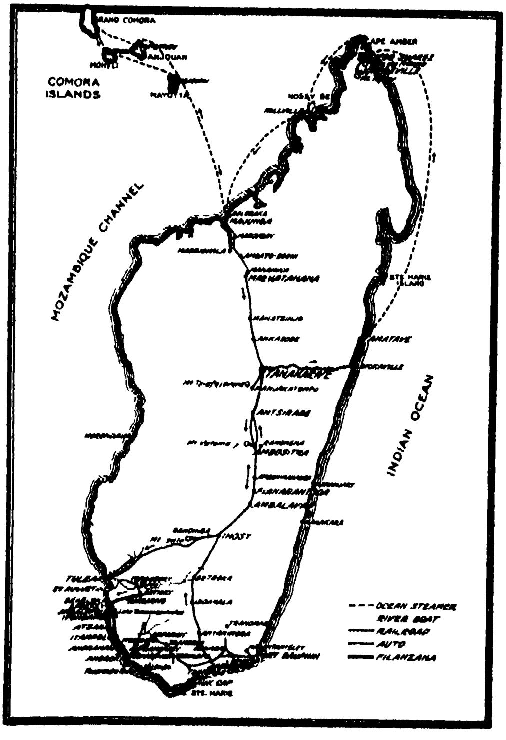
A net made to fit a cot does not fit a chair, so I dragged my own folding cot from underneath the ship's luggage, and looked around to find a spot to set it up It was necessary to capture a few second-class brown babies and restore them to their mothers, and to ask that outstretched feet be withdrawn over the imaginary line which marked the second class from the first, in order to spread the cot. The deck was so uneven that only the middle pair of legs touched, and I teetered ingloriously the entire night Every one who squeezed past my bed dislocated the netting and I was constantly having to adjust it. Of the many nights in Madagascar, this one made the most definite impression, probably because sleep robbed me of so few of its delights.

In the morning I looked out upon a tired, ravished country. Flat shore lines stretched back from either side, barren hills in the distance. I could scarcely believe that these river banks not so long ago were covered with dense virgin forests which had been despoiled by hand-set fires. I saw these fires being lit, and at one time could see smoke from eight separate conflagrations.

The easiest way to prepare for the cultivation of rice—the principal article of food in Madagascar—is to burn off the ground, and the natives never choose arduous labor. Surely there could be no better object lesson in conservation than these bleak hills on which only a few curious fire-resisting trees scraggled. Swarms of termites are the clean-up squad in this devastation of the forests. They build huge mounds, about the size of haycocks, and strangely, these mounds are distributed with almost geometric precision over the ground so that the landscape reminds one exactly of a field of hay ready to be hauled to the barn.

The smoke that we saw hanging on the horizon in every direction warned us that each day our expedition was delayed meant fewer plants for us to find. We knew that many plants formerly characteristic of Madagascar had already become completely exterminated, and I could only hope that intisy was not among them.

We were glad when we were per-



THE AUTHOR'S ROUTE, AND MEANS OF TRANSPORTATION EMPLOYED IN MADAGASCAR

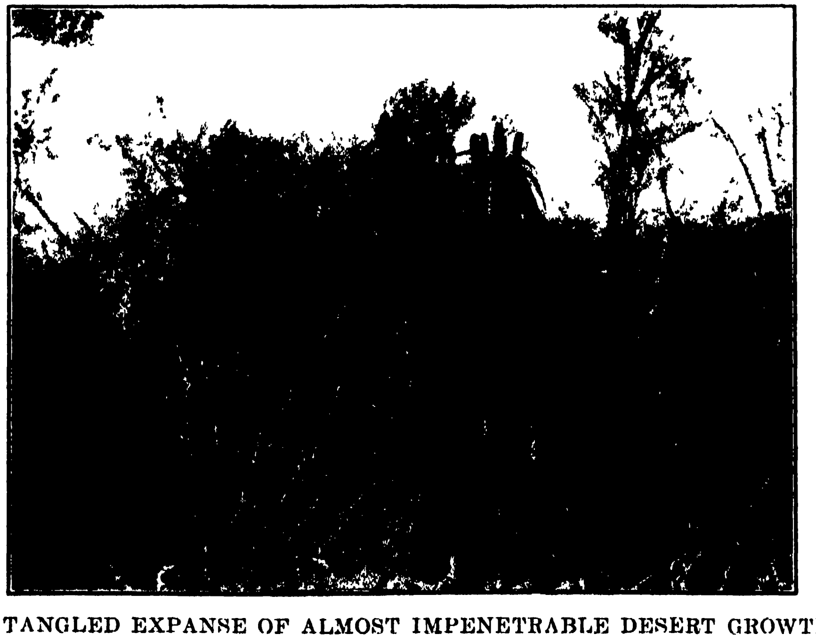
THE RELATIVELY UNKNOWN SOUTHWESTERN PART OF THE ISLAND WAS THE PRINCIPAL OBJECTIVE OF THE EXPEDITION.

MANY AN AMERICAN ICE-CREAM CONE HAS BEEN FLAVORED BY VANILLA WHICH GREW NEAR DZAOUDZI, COMORO ISLANDS

MOST OF THE WORLD'S SUPPLY OF VANILLA COMES FROM "MADAGASCAR AND DEPENDENCIES," THE LATTER BEING THE ISLANDS OF NOSSY-BE AND STE. MARIE, AND THE COMORO ISLANDS. THE HILL TO THE LEFT IS ONE RIM OF AN EXTINCT VOLCANO, ALL THE COMOROS BEING OF VOLCANIC ORIGIN

mitted to unload at a Sakalava village for a few hours before resuming our river trip. We were in the most torrid section of the island, and the surroundings were typical of native life. On the dusty road to the settlement oxcarts creaked along, brown men in loin cloths beside them, loaded with bales of raphia on their way to the landing place. Raphia, which comes from the young leaves of a palm, was interesting to me because I had used it many times for tying plants in greenhouses and nurseries in America

The bare little village lay along shaggy streets, squat and brown, looking as if its unburned brick huts had been tanned by the same fierce sun



"A TANGLED EXPANSE OF ALMOST IMPENETRABLE DESERT GROWTH"

A MARVELOUS ALOE WASTES ITS FRAGRANCE ON THE DESERT AIR.

which had browned the natives who moved with careless grace in and out of them.

Native homes in Madagascar are windowless, chimneyless dwellings, their walls smoked from open fires. In the northern part of the island, they are constructed mostly of unburned brick, in the southern quarter, of woven grass or bamboo.

Storekeeping in all villages is done by the Hindoo and Chinese merchants Curiously, a "Chinese store" is always a grocery, carrying French supplies, and a "Hindoo store" handles little except cloth. The good-natured and quite intelligent Malagash natives are childish when it comes to business dealings and are easily outwitted by the Hindoos and Chinese with whom they deal. Business is largely done by barter, for there is very little actual money in Madagascar, in spite of the richness of the island. If so small a sum as 10 francs (40 cents) is offered a native—and this represents a major purchase—almost invariably he will be unable to change it.

Goods including groceries, when not carried loose in baskets, are usually wrapped in discarded French newspapers, brought to the island expressly for this purpose, a paper bag being a rare thing. In fact, a container of any sort is something to be prized and one of the busiest spots in the market is the corner which handles discarded empty bottles, tin cans and boxes. An acquaintance I made, a French storekeeper, told me he handled an acknowledgedly inferior brand of bottled soda pop because the natives particularly liked the large false-bottom bottles it came in. We never threw away even so much as a match box or a tin foil wrapper without some native making a dash for it.

Again on the river, this time jammed into two small motor boats, we found ourselves rocking along through water alive with crocodiles. The day before we had passed the village of Marovoay, meaning "many crocodiles" and not extravagantly named, for we saw hundreds of these ugly fellows, stretched out in the sun asleep on the river banks. Out of the water, these vicious fellows

THE AUTHOR FINDS MANY INTERESTING PLANTS IN CENTRAL MADAGASCAR

"THE VERY GROTESQUENESS OF THE PLANTS SUGGESTED A SINISTER ALLUREMENT"

DR. HUMBERT STANDING BESIDE SOME OF THE DIDIEREAS.

are ignominious cowards, and at the first distant sound of our motor, they slid quickly into the water. Once in their own element, they lurked about hungrily, at a short distance. We would catch glimpses of wicked looking eyes protruding above the surface of the water, the rest of the head completely submerged. But if we were able to startle the crocodiles on the bank with a rifle shot, they, instead of gliding quietly into the water, sprang into it in

FIRES DON'T DISCOURAGE THESE

THE SCLEROCARYA AND THE MEDEMIA PALM ARE ABLE TO RESIST THE EVER-RECURRING GRASS FIRES OF THIS REGION. HAND-SET FIRES ARE ONE OF THE COMMONEST SIGHTS OF MADAGASCAR.

terror, and sank to the bottom of the stream where they crawled, completely defeated, their path indicated by bubbles on the surface.

It is an inviolate rule in Madagascar that one must never put hand or foot in water in which he can not see the bottom. Whenever one must wade in a stream, the natives beat and whip up the water with great force and shouting to frighten lurking monsters. One form of the old Madagascar trial by ordeal was to throw the suspected culprit into a crocodile-infested stream. If guilty, that was the end of him, if innocent, he made it across to the other shore

Natives seldom molest these dangerous creatures. It is not fear alone, but religious tabus which protect the crocodile and other reptiles in Madagascar. The native is willing to risk the crocodile's jaws, but dares not offend the crocodile's soul!

We had several hunters aboard, and with characteristic indifference to time or schedules, the boat veered and detoured constantly to give them opportunity to bag their game successfully. We found here, as everywhere, only astonishment or languid indifference to greet our ambitious planning for a speedy trip. It was as if a people existed who felt absolutely no resentment against the shortness of life and breath.

We felt as though we had gone through a modern trial by ordeal before the required three days of river travel were behind us and we struck the automobile road to the capital, Tananarive.

Excellent new roads built by crude hand labor seem unusual in a country with so few cars to use them Any motor vehicle was always a source of wonderment and almost fear to the Malagash natives. An automobile does not pass over this road every day, yet mile on mile of fine smooth highway stretches through the heart of the country and these roads are being continually extended.

ONCE SUPERB TROPICAL FOREST, NOW BARREN PRAIRIE COVERED WITH TERMITE NESTS

Our trip from the coast to Tananarive, only 250 miles on the map, had taken us six days, or virtually the same time as was required for this trip 50 years ago. It is certain that within a few months the highway will be completed

OXCARTS HELP, BUT DO NOT REPLACE THE HUMAN BACK IN MADAGASCAR

all the way, and buses will make the entire trip, eliminating the boats altogether. When this occurs, it will mean the passing of one of the most appallingly picturesque journeys of old Madagascar.

Our week in the capital city was one of constant planning for the days ahead. We must guard against accident to our precious collections which were already growing. We must take care lest some unforseen detail at Tulear would defeat us at the last in our determination to explore the southernmost area. Each of us must take on some twenty porters to transport us and our equipment into the desert—would we be able to find men willing to risk their lives with us? Always in my mind was anxiety lest I should find *Euphorbia intisy* already added to the long list of non-existent plants.

During our months of travel on the island we had only a few hours by rail, and were dependent on public bus or private cars the rest of the way. We slept in huts by the road, empty windowless houses, especially reserved for European travelers, and seldom occupied so they were free from filth and vermin. The roads in the southern half of Madagascar are strictly dry-weather conveniences, as there are no bridges, and when streams are high, they are impassable. Ferries are made by joining three or four tiny dugout canoes together, and laying a few boards across. They are made chiefly to accommodate foot passengers and on rare occasions automobiles.

It looked as if our expedition might come to an unceremonious end at one such crossing near Tulear. We arrived after dark at the water's edge with our truck heavily loaded with all of the equipment for the desert journey. We well knew the custom that no one on the island, regardless of the need, ever labors after the setting of the sun; but to spend the night here meant unloading the truck which had taken hours to pack. We were immediately refused when we asked the natives to help us across. It was dark, they told us, the river was high, and what was final, the ferry was broken. We pled and argued,

and, finally, when we offered liberal tips, help became plentiful, the river negotiable, and the ferry ready to go.

It was a perilous undertaking. With the small canoes together, and planked, we found we had only four inches to spare at either end of the raft. It required eight men to hold it to keep it from skidding out from under as we manouvered the truck into position and blocked its wheels in place. The river was swift and deep and teeming with crocodiles. Our overloaded truck forced the ferry almost level with the water. The crossing was effected by a sort of an endless rope arrangement with the ferry fastened to the rope. Two natives slowly pulled the boat across with our most fervent good wishes and prayers to assist them. Once over, it was a long task to build a trustworthy landing on the bank. When we were safely on solid ground again, my traveling companion, who could speak little English, and I, who could speak little French, congratulated each other, and each of us understood perfectly.

At Tulear, good luck was with us and French authority was brought to bear on the natives we needed for carriers. They were simply drafted into our service from several villages and gathered at Betioky where we were to start into to brush. Much as we needed them we could not but sympathize heartily with their protests against such an excursion. It was the first instance we saw of any sullenness among the Malagash, and it was undoubtedly justified as events later proved.

These Malagash people are not, as one would suppose, black men like their African neighbors only 240 miles away. Strange to say, they have practically the same language and similar appearance as the Sumatrans, with 3,000 miles of ocean between them. They are erect, straight haired, brown Melayo-Melane-

DRIED GRASSHOPPERS OCCUPY A PROMINENT PART OF THE MARKET IN MADAGASCAR

FOR ONLY A SOU (ONE-FIFTH OF A CENT) ONE CAN PURCHASE A WHOLE PILE OF THESE TASTY CREATURES. OTHER PEOPLES MAY LOOK UPON GRASSHOPPERS AS A CRUEL VISITATION OF PROVIDENCE. NOT SO THE MALAGASH; TO THEM IT MEANS A PERIOD OF FEASTING, FOR GRASSHOPPERS ARE A CHOICE VIAND ON THE ISLAND.

NOT A KU KLUX GATHERING BUT A CORNER OF THE *ZOMA* AT TANANARIVE ON MARKET DAY

sians. In the south of the island they are frequently dressed only in their loin cloths, the men carrying spears as the sign of gentlemen. In the more populated northern sections the people are clothed in ridiculous second-hand European garments shipped there for sale, with their native *lambas* (shawls) wrapped over all. I was quite startled one day to observe a dusky grinning

EVERY DAY IS MARKET DAY AT AMPANIHY

NOTE THE PREVALENCE OF "SUNTAN BACKS" AND THE GENEROUS USE OF TALLOW IN ARRANGING MILADY'S COIFFURE.

Malagash lad wearing a hat on which was displayed the proud name of Rugby!

A gathering of Malagash natives reminded me of "roughneck" day, years before, on my college campus, when all students gleefully dressed themselves in the most incongruous apparel they could assemble to celebrate the Ides of March Top hats and bare shins, dress coats over night shirts, and Spanish combs in unruly locks—fashion's mandates are elastic in Madagascar.

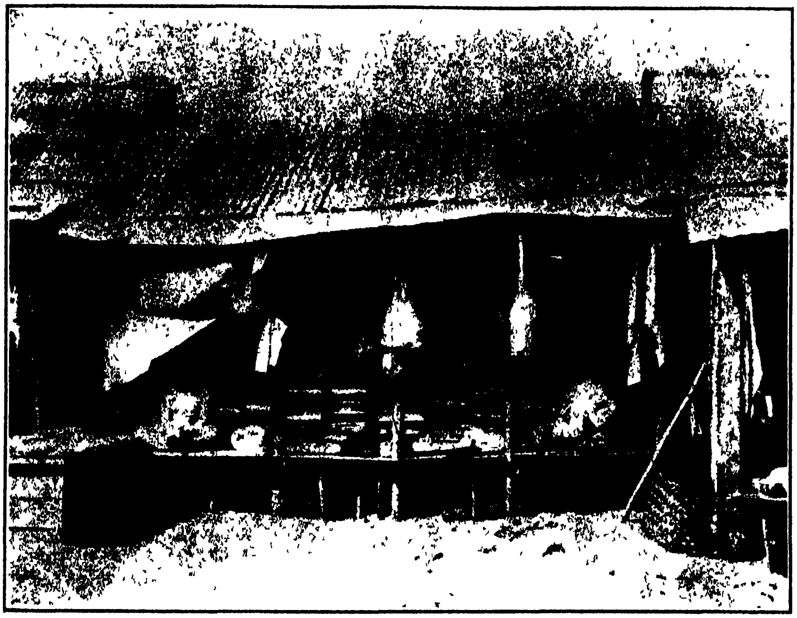
They are a patient, happy race, naive in their ideas of morality, to be sure, but a decent, likable lot.

We had two chauffeurs on part of our journey who, when they presented themselves, told us they were brothers.

"But how is it," I inquired, "that you two, who are brothers, look so unlike?"

They replied: "With you, we are told, whole families often have the same father. To us, this seems very hard to understand."

The one evidence of earthly ambition on the part of the natives is their passion for acquiring herds of zebu cattle. The size of their flocks is their one measure of worldly standing. These cattle are never fed, are seldom driven to water, and are rarely milked or killed for food.



Photograph by Dick Delonlay

MADAGASCAR HAS MANY CLOTHING STORES SUCH AS THIS, BUT FEW GROCERY STORES

THIS IS A TYPICAL "HINDOO SHOP," WHILE MOST OF THE GROCERY STORES, FOR EQUALLY OBVIOUS REASONS, ARE KNOWN AS "CHINESE SHOPS."

The incident was told me of a prosperous Malagash native whose wife and very young infant were suffering from cold, being destitute of clothing. He was brought before a colonial official and rebuked for allowing his wife to die of neglect while he was rich in cattle.

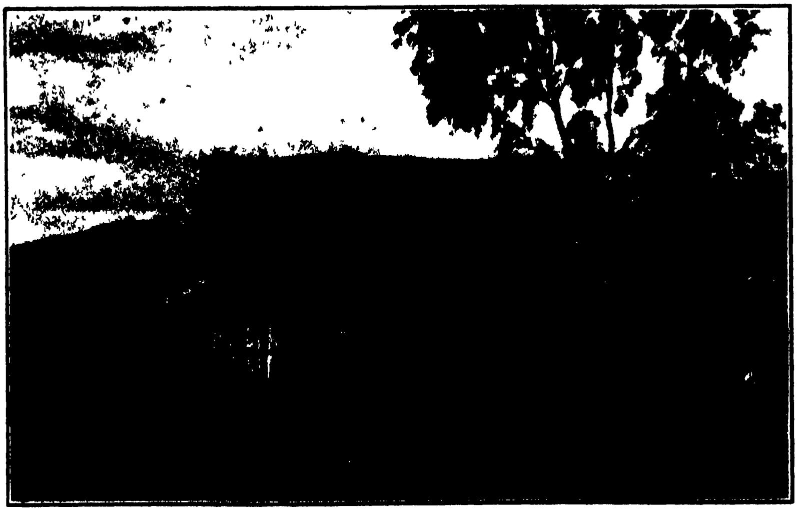
"But if I part with a zebu," he replied, "It is so very hard to get another."

At Betioky, we were to lose all communication with civilization for a time.

FRAIL GRASS HUTS ARE THE RULE IN SOUTHERN MADAGASCAR

Mail communication was almost a negligible factor with us at any time, as it requires many weeks to send letters across the island, a very excellent and cheap telegraph system being universally depended upon. Courier service is sometimes used for short-distance mail service between officials or Europeans quite generally, and was amusing to us. A note is given to the native carrier who places it in the end of a split stick, and as he runs with it to its destination he offers it to every European he meets. The message usually reaches the intended person eventually, though I would not recommend sending secret information by this means.

Under a cloudless sky, our filanzana



THE "HOTEL" AT MAHATSINJO

THE AUTHOR SPENT MANY NIGHTS IN HUTS SUCH AS THIS.

expedition set out into the desert. During half of each year there is absolutely no rainfall here and drouths lasting as long as six years have been known.

Thrilling stories had drifted out of the brush, and others will never be known. We knew the authentic story of Dr. Brown, the young Carnegie surveyor, whose trail we were partially to follow. He was proceeding as we were, by filanzana, and was several days out when his water supply was exhausted. Even his porters had refused the only moisture to be had, foul mud at the bottom of a water hole. It seemed that but one fate awaited the party, several days away from water in any direction, under a fierce tropical sun. But in the night, miraculously, for it was the first time in three years, a shower fell. The porters rushed to spread their lambas to catch the precious drops—lambas which probably had not been washed since the last rain—and obtained drinking water by wringing them out into their calabash vessels.

Small wonder that our porters grumbled over a similar excursion!

That plant life should be so abundant in this rainless country seems almost incredible. It is made possible only by the very great humidity at night. Dense dews and fogs occur almost nightly. The dew on a large plant becomes so heavy during the night that it often runs down about the base, and in the morning the ground about the plant looks as if it had been wet by a shower. The desert plants have developed water-utilizing devices of various queer sorts which render them resistant to the unusual drouth conditions.

Minutes in the morning on the desert are precious, so Dr. Humbert and I brewed a hasty cup of cocoa at dawn each day, and with little more for

Photograph by Dick Delonlay

DWELLINGS OF UNBURNED BRICK PREDOMINATE IN CENTRAL AND NORTHERN MADAGASCAR

NOTE THAT THE HOUSES ARE WITHOUT CHIMNEYS.

Photograph by Robert Taylor.

WOOD CARVING IS ALSO A FAVORITE PASTIME FOR MANY OF THE MALAGASH

breakfast, climbed into our filanzanas—swinging chairs borne by two long horizontal poles. The natives did not breakfast at all until late in the morning, and sometimes they had their first meal long after noon.

The dismal chill of the early hours was as difficult to withstand as the heat later on. I began the day wearing a khaki shirt, a sweater, a coat, and a light overcoat, but even so I was never quite warm enough for comfort.

Four natives picked up each of our two curious filanzana chairs and jogged off. One porter could work only about five minutes without needing relief, then he would manipulate a shift with his alternate. Every step of the porters is a jar to the passenger, and each shift a real jolt. No two of the porters were the same height, and the bobbing about was indescribably fatiguing. The first morning while I was attempting to adjust myself to the discomfort a porter stumbled while making the shift, and I was dumped out into the path.

The porters were an irresponsible, joking group, talkative to the point of irritation at times. My filanzana was decorated with the personal belongings of my men—foot shields cut from goat skins, charms, souvenirs, spoons for their rice, and even tiny woven mats for their beds. We had to threaten to strap the two camera porters to the filanzana also, as they were constantly wandering ahead or lagging behind when we needed the camera. Moreover, although the

water supply was all important, we had to watch the natives every morning to see that each filled his individual calabash, for during the day the large water bags were with the baggage carriers who might be miles ahead of our more leisurely group.

Our experience differed from that of the average plant collector, in that we seldom had to reconnoiter for specimens, as the place was untouched by botanists and we were surrounded by plant life as we followed the trail. It was rest from our uncomfortable riding to get down and gather plants, and at intervals we would walk for periods of half an hour or so to rest the porters. An hour's walk is a very long one for a white man in any part of Madagascar, and is only rarely made by a European Automobiles being scarce, white men use, whenever the road permits, rickshaws pulled and shoved by "*pousse-pousse*" boys. Of course we had no such de luxe service in the brush.

About eleven o'clock the desert heat was upon us in its full intensity, and we made our long stop. How the natives could endure this tropical sun with no protective head covering is a source of wonder. It is considered by those who know the climate best to be positively dangerous to go without a helmet for even five minutes. White men's helmets do not come off outdoors, even in the shade. The blinding glare of the desert sun would have been almost unendurable had it not been for occasional tall, spreading tamarind trees, which afforded the only real shade in the desert. We always made our stop under one if possible.

The porters cooked their main meal at this time. Sometimes it consisted of manioc or of sweet potatoes, but the usual meal was of rice. Each man had the unbelievable allotment of more than two pounds of dry rice a day which he actually consumed, sometimes at one meal. It was really well cooked, each grain flaky and whole, though unsalted. It was boiled exactly twenty-five min-

Photograph by Dick Delonlay.

HOVA WOMAN WEAVING A SILK LAMBA ON A NATIVE LOOM

TRAVELING BY AUTO IN MADAGASCAR IS NOT AS SIMPLE AS IT SOUNDS

FORTUNATELY MEN AND WOMEN OF THE VILLAGES WERE ALWAYS WILLING TO TURN OUT AND LEND A HAND.

utes, and so exact are they in this that they are accustomed to measure time by the length of their rice cooking.

Occasionally we purchased a desert-herded animal to slaughter for meat. But supplying the group with meat was complicated, because of the tabus certain tribes held against certain meats. Our men were of several tribes and broke up into tribal groups for their eating. Some could not eat beef, some could not eat mutton or goat meat. They were quiet about these idiosyncrasies, and often we did not know of their shortage of food until they felt it on the march. We always carried a few live chickens with us, and these were an unmixed blessing to Dr. Humbert and me, who had to prepare our own meals. We could not obtain a cook (this sounds like civilization), and consequently depended on our own culinary efforts, with but slight help from the native soldier in our party who sometimes tried to aid at mealtime.

The porters sometimes took advantage of the strong light at noon to dig out chiggers from their feet. The feet of all were badly mutilated with gouging out these pests. Chigger hunting is a very necessary rite in all parts of the island as this tiny mite is a very serious scourge. During my three and one-half months in Madagascar my unshod feet never touched the floor or ground for danger of picking up one of these tiny mites. They are extremely minute, so small that I never managed to spy one, although I saw natives everywhere searching them out. They burrow under the nails or under the thick callouses on the soles of the feet, lay their eggs and incubate them. The ensuing poisoning is very serious and sometimes fatal. Native girls of keen eyesight find chigger hunting a paying occupation. Often they find the chigger buried a quarter of an inch. It is not an outdoor mite, but one that infests only buildings, hiding in crevices and corners.

Occasionally, during our stops there were complications with our porters which we must straighten out. Leprosy is very common on the island, and we saw many persons whom we had cause to suspect. At one village, isolated to the outskirts, we came upon a leper, a woman so ravished by the disease that she appeared aged and revolting. The porters began chatting with her in their customary easygoing way, and were not the least bit fearful. We were concerned over the situation. We finally gave the chief of the village a few francs, asking him to give them to the creature, with instructions that she keep away from our men. We were somewhat taken aback to find that, having opulence thus thrust upon her, the woman immediately began buying trinkets from our porters, and a merry exchange of goods was going on before we could put a stop to it

We always took advantage of the noon-day sun to assist us in drying such of our specimens as we wished to preserve in the dry state. Dr. Humbert was especially responsible for gathering and classifying these dry herbarium specimens, while I had been sent particularly to bring back living plants. No collection in America had a display of Madagascar plants, either living or dead, and it was to remedy this lack that our expedition had been organized by the Arnold Arboretum of Harvard University, and the United States Department of Agriculture, in conjunction with the University of Algiers

These desert plants, because of their ability to store and utilize water in their leaves, stems and roots, were very difficult to dry between blotters as is the usual process, and our problem was to speed up the drying, avoiding rain and dew, and using every minute of sunshine we could. The plants we gathered as we marched, and carefully placed

IT ISN'T EVERY YEAR THAT THEY HAVE A CHANCE TO OBSERVE A WHITE VISITOR

CURIOUS NATIVES ALWAYS GATHER AT THE "CASE PASSAGE" OR TRAVELER'S HUT WHICH IS PROVIDED IN EVERY REMOTE SECTION OF MADAGASCAR FOR THE USE OF EUROPEAN VISITORS.

MEAL TIME

HATS MAKE FINE PLATES FOR SERVING RICE.

them into baskets Each plant had to be removed from the ground in as nearly a perfect state as possible. We did not trust our porters to do this particular work. Always must we find plants that were in bloom, for of course to be of much use as herbarium specimens, they must have a good, open blossom. Whenever we could find them, we dug up twenty or thirty of each kind, carefully tying them together.

Within a few minutes after making our noon-day stop our camp would take on a queer cluttered appearance as we untied bulky bundles of blotters and laid them out in little piles in the sun to dry, carefully weighting them down with sticks and stones to keep them from blowing. Many of the recently gathered plants had to be cut into several pieces to be accommodated, for blossoms, stems, roots and all must be placed between special absorbent sheets of paper. With few exceptions, our plants were never pressed as one might suppose; no pressure was brought to bear on any of them except that caused by the straps used to bundle the unwieldy layers of blotters together. We carried a queer collection of jars and bottles and preserving solutions for fleshy forms impossible to dry.

Occasionally on coming to a village, we found it necessary to stop and dry out plants and blotters with artificial heat. We would construct racks 15 or 20 feet long, 3 feet off the ground, out of small tree trunks, laying out our piles of blotters on them. Underneath we would build a slow, smoldering line of fire which had to be kept burning steadily but not blazing.

While we did our clerical work, or ironed other plants with a sad-iron to dry them, we had a native tend this fire. On one stop we employed a boy for this work, but we were continually irritated to step from the house in which we were working to find him gone. Finally I decided to accomplish our ends by gentle means, so I bought him a nickel's worth of bananas—an enormous number for one boy—and two cents' worth of peanuts. Capturing him down the street

I escorted him back to our camp and urged him to make himself contented by the fire with food and reverie. Returning an hour later I found the fire out, the fifteen or twenty bananas gone, the peanuts consumed, and the boy stretched out in the sun, sleeping peacefully.

Properly dried herbarium specimens will last in usable condition for centuries. Botanists to-day are using some prepared by Linnaeus, "the father of botany," two hundred years ago. But improperly cared-for specimens mold and are ruined within a few days. The reader can conceive of the labor connected with such an enterprise as ours, when he knows that besides the living plant material we brought back some 3,000 herbarium numbers, each number representing five to thirty plants in flower, each specimen having gone through a drying process of from several days to several weeks We must always know the exact locality in which we collected each plant, and the date, and our best tentative field classification needed to be made in every case.

Afternoon on the desert was a repetition of the morning, and our two filanzanas often traveled several miles apart as each of us paused and gathered material. Evening camp was made early to enable us to care for the day's accumulation of plants.

Many a night after a strenuous day of collecting I worked until one or two in the morning caring for my living plants, with a sunrise start to make next day. These could not accumulate as the dry specimens might if necessary. The living plant material must be wrapped in paper in small bundles, keeping varieties and lots separate, and packed in tin cracker boxes. When I landed in Madagascar, short of packing material for my plants, I bought a few cents' worth of coconut husks—the thick fibrous covering which grows around the coconut—and five or six men spent the day shredding this for me, to the great amusement of the other natives. I also used the

ACROSS THE MAHAFALY PLATEAU

THE EXPEDITION ON THE MARCH.

THE AUTHOR IN HIS MADAGASCAR PRAIRIE SCHOONER
FILANZANA TRAVEL HAS LITTLE TO OFFER IN THE WAY OF COMFORT OR SPEED.

roots of ferns which grow on the trunks of trees, as a satisfactory makeshift for really desirable moss, of which I found but little in Madagascar My entire collection of plants had to be gone over thoroughly very often, rewrapping and discarding where necessary. Naturally, seeds are by far the easiest of living plant material to handle, and these I obtained whenever possible.

With nightfall the clammy desert chill sent us to our wraps and blankets, but the natives lay on the bare ground around the ashes of their fires, with only their thin lambas for protection from the cold.

The responsibility for the lives of our forty men in a country where water was so difficult to obtain was no slight one. They had been forced to accompany us and I felt real concern for their safety as well as for our own. We had started with all the water it was possible for us to carry, but it was necessary for us to plan to fill our water bags at village waterholes along the way.

It looked as if the porters' fears were to be swiftly realized, when at the end of the second day's march our water supply ran out. We had found that the two or three tiny villages we passed had not enough water for their own needs, and drinking water and water for cooking rice for our large party was simply unobtainable. Our only hope was to push ahead the third day, as quickly as possible, trusting to find a sufficient supply before it was too late.

Our physical suffering and our torturing thoughts that day, struggling under a merciless sun, are indescribable. An ominous hush fell over the party. It was not broken when, one after another, five of our faithful porters collapsed by the roadside. We paused only to moisten the lips of the first two with the last hoarded drops of water—we could do nothing for the other three. We marched on silently in the desperate hope that we might return to them before it was too late. Of course we could no longer depend on filanzana travel and in spite of our exhaustion we must take up the uncertain journey on foot.

Toward the middle of the afternoon we sighted a village ahead, and we found to our joy enough water there so that each of our half-crazed men might have a sip.

We were too weakened to return for our fallen men, but villagers were sent to rescue them. Very fortunately, they were all resuscitated, although two were of no more assistance to us, and had not recovered fully when we parted from them at the end of the trip. Separated from others in the party which made a trip to a distant waterhole later that afternoon, I collapsed twice, and was only fortunate in recovering consciousness and strength to the point where I could resume the walk.

Our progress was much slowed down after this harrowing experience, as all of us were much affected. Moreover, during the weeks in the desert which followed, we were constantly tormented by the shortage of water, at best being forced to drink from reeking waterholes after animals had fouled them, at worst, going without. Swallowing our daily dose of quinine was truly a pleasant process, for it took away the nauseating taste of the awful water.

The first day out I had said to the chief of the porters, "Do you know the rubber plant called *intisy?*"

"Eka (yes)," came the answer we hardly dared expect.

"How far is it?"

"We will surely find it right on our path within a few hours," he promised. We started in great anticipation, and surely enough within a few hours he proudly pointed out his treasure. Imagine our sickening realization that it was a totally different rubber plant, of inferior quality, and one already in our collection!

We had been in the desert two weeks and as yet there had not been a trace of the plant Members of our own party had not attempted to offer more information after the first day, but other natives, of whom we were constantly inquiring, were certain they could direct us to the plant. But their reassuring predictions, though exceedingly well

SOME OF THE ORIGINAL INTISY PLANTS, AND A FEW OF THE PROPAGATIONS, IN THE WASHINGTON GREENHOUSES

THE FIRST PLANT OF *EUPHORBIA INTISY* FOUND BY THE EXPEDITION

THIS IS "AN INCONSPICUOUS LITTLE TREE WITH LEAFLESS GREEN BRANCHES," BUT IT YIELDS ONE OF THE BEST RUBBERS KNOWN, AND FOR THIS REASON IT HAS BEEN VIRTUALLY EXTERMINATED BY THE MADAGASCAR NATIVES.

meant, served only to increase our disappointment at finding none of them to be true.

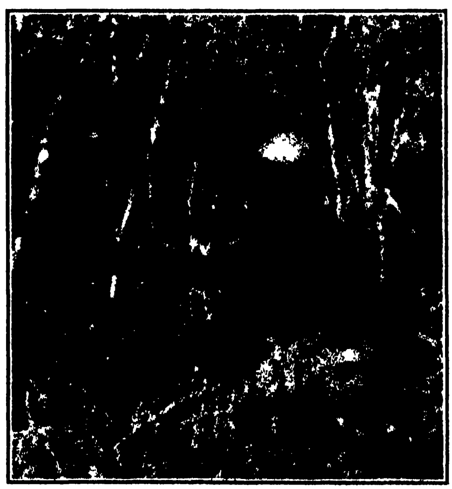
A village chief had been our latest informant and after a tedious excursion we found that his information was as useless as all the rest had been. Almost with resentment I listened to the words of cheer he poured out to us as we departed.

"I know now which one you wish, don't be sad for you will find it a few hours on."

Scarcely two hours later, as my porters jogged along, I looked up to see a slender, inconspicuous little tree with leafless green branches, growing in the brush at the side of the road. I was almost too excited to shout "Andras (stop)!" to my brown men.

I was out of the filanzana and scrambling through the brush in a minute. Once I had reached the tree I felt certain it was intisy, but I took my knife and anxiously made a slash in one of the slender stems, and watched the milk latex ooze out. Dipping my finger in this white liquid, I gleefully saw it harden into a gummy mass of almost pure rubber, and I knew that at last I had come upon my coveted *Euphorbia intisy*. No other rubber plant is known which produces a latex that hardens into such high-quality rubber entirely without artificial treatment. It is the fact that this high-quality rubber can be handled with such ease, which accounts for its exploitation by the natives. Many years ago all accessible trees had been slashed mercilessly and soon killed by their ruthless methods of rubber collecting.

"Two francs (eight cents, or a day's wages) for each plant like this you can dig up and bring us!" I told my porters, and they scattered out to find other specimens. Their enthusiasm did not last long however, when they found the little trees were in dry stony ground, and very difficult to dig without injuring the very queer roots with which they were equipped. Intisy differs from



DIGGING INTISY PLANTS OUT OF DRY, STONY SOIL WAS HARD AND UNUSUAL WORK FOR THE PORTERS

any known plant, having roots which store water in bulbous swellings which occur one after another, like link sausages.

After finding intisy, my care for my live plants was all the more vigilant. On coming to a village, my first concern was to secure tin cracker boxes which I used as containers for many plants on the entire return voyage.

I stepped into a Hindoo store at one point which carried a little candy in addition to its usual stock of cloth.

"Have you any empty tin boxes?" I asked

The search turned up a greasy box which was offered confidently

"No it's too dirty for me to put my plants in," I told him.

"Oh, that's all right," the obliging shopkeeper replied, dumping the contents of a half-empty candy box into the despised container. "The dirty one is quite as good to me!"

Once out of the desert, we sent the porters back on foot, by a short route, and I turned homeward with my living plants. If I had gone through every privation to obtain them, once on shipboard, I was speeded on my way with all that modern transportation could do to aid me. I was assured that no quarter on the boat was too good for my queer luggage, and every day I must open each box to air and syringe and examine my specimens. Before sailing I had picked up eight miniature greenhouses which I had taken to the island full of choice citrus plants, a gift from our government to the Madagascar government, and these were now full of island plants making the trip to America. My most troublesome piece of baggage was an enamel kettle full of plants in a liquid preservative which I carried 10,000 miles with only a leaky cover, there being no tight container obtainable in Madagascar.

In each of my twenty-three pieces of luggage I had tucked specimens of intisy, so that nothing but the sinking of the vessel would have robbed me of *all* my spoils. I am quite sure that had I gone to the bottom of the Atlantic, I would have had intisy in all my pockets!

To what extent this queer plant will permit itself to become Americanized, no one can say. The fact that specimens of intisy are now thriving in Florida and California leads us to hope that the question will not long remain unanswered.

A CINEMATOGRAPHIC STUDY OF SPRINTERS

By Professor WALLACE O. FENN

THE SCHOOL OF MEDICINE AND DENTISTRY OF THE UNIVERSITY OF ROCHESTER

THE earliest incentive to the development of the motion picture was the desire to study the gaits of animals and the foot movements of the race horse (Muybridge, 1873).[1] Likewise the pioneer efforts in 1885 of the French physiologist, Marey,[2] in this direction, were particularly devoted toward the study of the movements of the limbs of men in running and walking. In more than forty years which have elapsed since that time the motion picture industry has passed far beyond its original objective. Simultaneously both the science and the art of running have advanced. On the one hand the physiologist has learned much concerning muscles and muscular movements which was unknown to Marey, and on the other hand sportsmen have accumulated a greater wealth of practical experience and empirical rules which have helped to make good runners and to break many world's records.

The moving pictures have contributed something to this advance but this contribution has been chiefly to the "anatomy" of running; it has described for us the orbits of the arms and legs in good and bad runners and has defined the times of contractions and relaxation of the various muscles. The moving pictures have not told us much, however, concerning the fundamental *physiology* of sprint running. It may be of interest, therefore, to describe the results of a cinematographic study of sprinters which has thrown some light on the fundamental question, "What is the limiting factor in running?" Why can man never attain a speed greater than a mere 10.6 meter per second? Why does it become increasingly difficult to beat a world's record?

For the moving pictures used in this study[3] I am indebted to Mr. C. A. Morrison, of the Eastman Teaching Medical Films. The general appearance of the films can be seen from Fig. 1, which shows a man running behind a lattice work with squares 1 meter on a side. There were 128 exposures per second, the length of each exposure lasting about one-thousandth of a second. The man wore a white collar with a black spot on it and a little marker with another black spot tied securely around the waist. These provided fixed points for measurement in determining the forward progress of the body and its rise and fall with each step. Croquet balls are dropped along the side of the frame-work in order to measure the speed of the film. One of these can be seen falling in Fig 2. The details of the methods used for the study of the films need not concern us here. Only the general argument which led to the taking of the films and the conclusions drawn from the study will be outlined in what follows.

THE EXTERNAL RESISTANCE

The runner appears to be pushing against a negligible external resistance, the air. This air resistance has been measured on small models of men in-

[1] Muybridge, "Animal Locomotion." London, 1873.

[2] E. J. Marey, "Developpement de la méthode graphique par l'emploi de la photographie," 1885.

[3] W. O. Fenn, "Frictional and Kinetic Factors in the Work of Sprint Running," *Amer. Jour. Physiol.*, 92, 583, 1930; "Work Against Gravity and Work Due to Velocity Changes in Running," *Amer. Jour. Physiol.*, 93, 433, 1930.

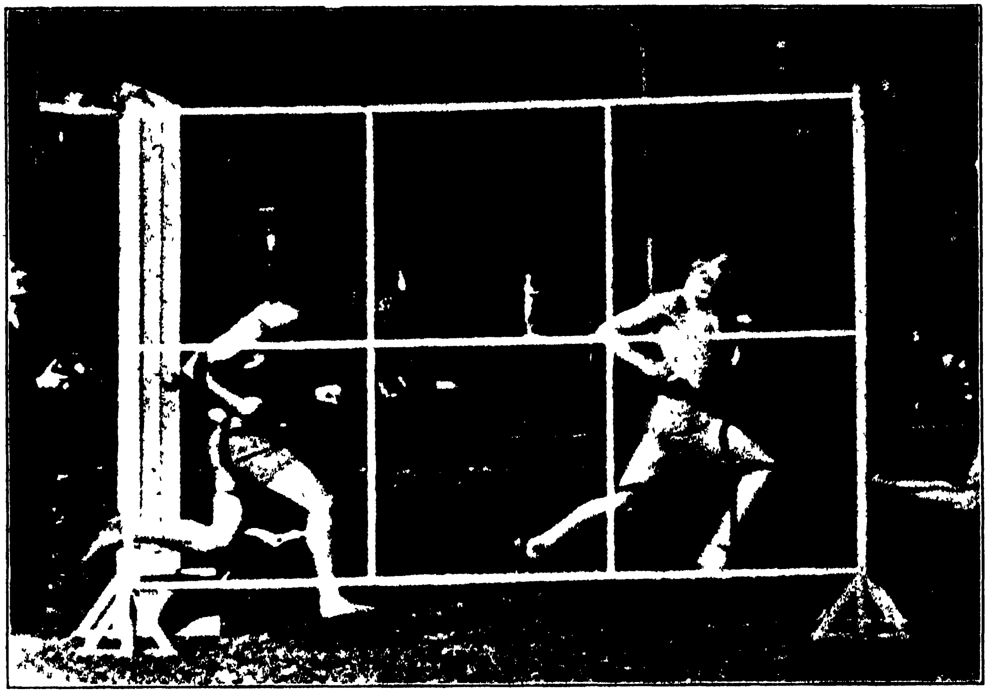


FIG. 1. SAMPLE FROM THE MOVING PICTURES USED FOR THE STUDY OF THE MECHANICS OF SPRINTING. THE SECOND RUNNER SHOWS A BLACK SPOT ATTACHED TO THE BELT BEHIND. BOTH RUNNERS HAVE BLACK SPOTS ON THE NECK BAND.

dependently by DuBois Reymond and by A. V. Hill, and the figure they obtained has been confirmed by the writer by quite a different method. Thus it has been found that for an average man running at top speed (7.5 meters per second) the air resistance is about 1.2 kgm. This is certainly a rather small resistance to be overcome by a man who at the start of a race can exert an average force more like 50 kgm. (Hill). Yet when going at maximum and hence constant speed the average propelling force must be just equal to the resisting force.

There is, however, another source of external resistance and this is the resistance offered by the ground. The foot does not strike the ground directly under the runner but somewhat in front of him. In fact a study of the moving pictures shows that the leg makes an angle with the ground at the moment of contact of 70-80 degrees instead of 90 degrees. This can be seen clearly in the second runner in Fig. 1. The result is that the runner tends to check his speed slightly each time his foot touches the ground. If one knows the location of the center of gravity of the body as well as its velocity at the moment of contact and its direction of movement then it is possible to calculate from the angle of contact how large this check on the movement of the runner is. Carrying out this relatively simple calculation it is found that the runner loses at each contact about 1½ per cent. of his velocity. At speeds of 7.5 meters per second, which are about maximum for most untrained runners, this amounts on the average to about twice the resistance offered by the air. This resistance is overcome by the foot while it is in contact with the ground as it gives a forward push to the body.

It is theoretically possible to measure this ground resistance also by determining from the moving picture film the maximum change in velocity of the body during each step. This was in fact done, but it turned out to be much more difficult and much less accurate than had been expected Unfortunately, the velocity of the body is, strictly, the velocity of its center of gravity, and this is by no means the same as the velocity of the nose or the hips or of any other part of the body. While the foot is on the ground the hips tend to get ahead of the nose, and while the runner is in the air the nose tends to catch up again. These changes in velocity are much greater fortunately than the changes in velocity of the center of gravity. This can clearly be shown by the laborious process of calculating from the various positions of the arms and legs at each moment in the race exactly where the center of gravity is. This calculation may be avoided by the use of the strange mechanical model illustrated in Fig. 2. This model was designed by O. Fischer.[4] It utilizes a series of interconnected pantographs each one of which has its terminals connected to the centers of gravities of two adjoining parts of the body and by its central point indicates the common center of gravity of these two parts irrespective of any change in their relative positions. Thus two pantographs on each leg indicate its common center of gravity ($S_{3,5,7}$) in whatever ways the knee and ankle may be bent. The common center of gravity of both legs (S_{2h187}) is indicated by another pantograph connecting the centers of gravity of the two legs separately. Still another pantograph indicates the combined center of gravity of the two legs and the body, and so on. Finally the point

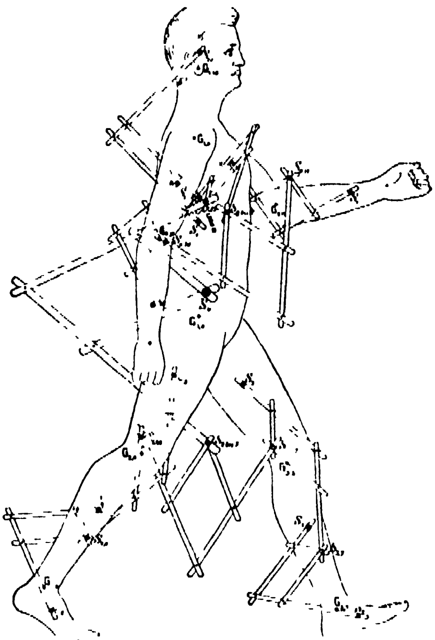


FIG. 2. THE POINT S_0 IN THIS SERIES OF PANTOGRAPHS INDICATES THE MOVEMENTS OF THE CENTER OF GRAVITY OF THE WHOLE BODY AS THE MAN WALKS. THE POINTS S_1, S_2, ETC., INDICATE THE FIXED POSITIONS OF THE CENTERS OF GRAVITY OF THE SEPARATE PARTS OF THE BODY. APPARATUS OF O. FISCHER.

S_0 (Fig. 2) indicates the center of gravity of the whole body for any position of the arms or legs. Even this method of following the center of gravity of the body is laborious enough and in any case the error is so large that the results are of no value for this purpose.

The most accurate and the most elegant method of measuring the ground resistance is to construct a small movable platform which is incorporated into a running track (Fig. 3). The runner arranges to step on this platform as he runs. The platform is mounted on wheels and moves very slightly backwards and forwards against strong springs and records its horizontal movements by a lever writing on a moving drum beside the running track. Thus it is possible to

[4] This model is reproduced in "Mechanik der Gelenke," by R. Fick, Vol. II, page 345, 1910. It is actually manufactured by E. Zimmermann, Berlin.

measure exactly what forces are exerted horizontally against the ground both when the foot strikes the ground and when it leaves it. In this way it is found that the total average external resistance (ground resistance plus air resistance) is about 5 kgm. for a man running at 7.5 meters per second and requires half a horse power of energy expenditure to overcome it (air resistance 0.16 horse power, ground resistance about twice as great, 0.34 horse power) This method gives a result therefore which agrees with the more approximate estimate reached from a study of the moving pictures.

Incidentally it may be added that the mean difference between the forward pressure recorded when the foot strikes the platform and the backward pressure recorded when it leaves provides a measure of the air resistance to motion 1.6 kgm. which agrees well with the figure 1.2 kgm. obtained on miniature men by Du Bois Reymond as described above.

The Total Horse Power Available for a Sprint

We learn from these observations that energy must be expended in a race at the rate of half a horse power in order to overcome the external resistance. It becomes of interest and importance therefore to inquire what the total horse power expended by the man is. This can be determined in the following manner. For a sprint of a given distance a man consumes a certain extra amount of oxygen every liter of which is equivalent to 5 large calories of energy For a sprint lasting 10 seconds we may say that he consumes one tenth of this total excess oxygen per second. More or less arbitrary, but unimportant corrections should be made to allow for the energy expended in bringing the body to maximum speed and in slowing it up again at the end of the end of the race.[5] The final result gives us the rate of energy expenditure or the total horse power developed in running at top speed. In carrying out this measurement the basal rate of oxygen consumption is first determined. Then at a given signal the runner holds his breath and sprints down a long corridor. He makes his next expiration into a rubber bag or spirometer at the end of the corridor so that all his expired air for the next half hour or more can be collected and analyzed. The results which we have obtained in this way on 19 different runners give an average figure of 13.2 horse power. According to the measurements of A. V. Hill[6] only a little less than half of this total energy would be available during the actual race. This is drawn from reserves within the body (probably phosphocreatine breakdown) which are replenished in recovery. Therefore, we may estimate the total energy expended during the race at 6 horse power. Only one twelfth of the total energy available is therefore used in overcoming the external resistance.

Some work is also done against gravity in running. The body rises and falls slightly at each step and this amount can also be determined from the moving pictures. This item amounts to an additional 0.1 horse power. Thus out of a total of 6 horse power only 1/10 has been accounted for.

Swinging the Arms and Legs—The Internal Resistance

These results, however, do not tell us the limiting factor—why we can not run any faster. They only tell us how much external propelling force we exert at maximum speed. What we want to know is why we can not expend a

[5] This is the method described by R. M. Sargent, 1926. Proc. Roy. Soc. B, c, 10.

[6] A. V. Hill, "Muscular Activity," Baltimore, 1926.

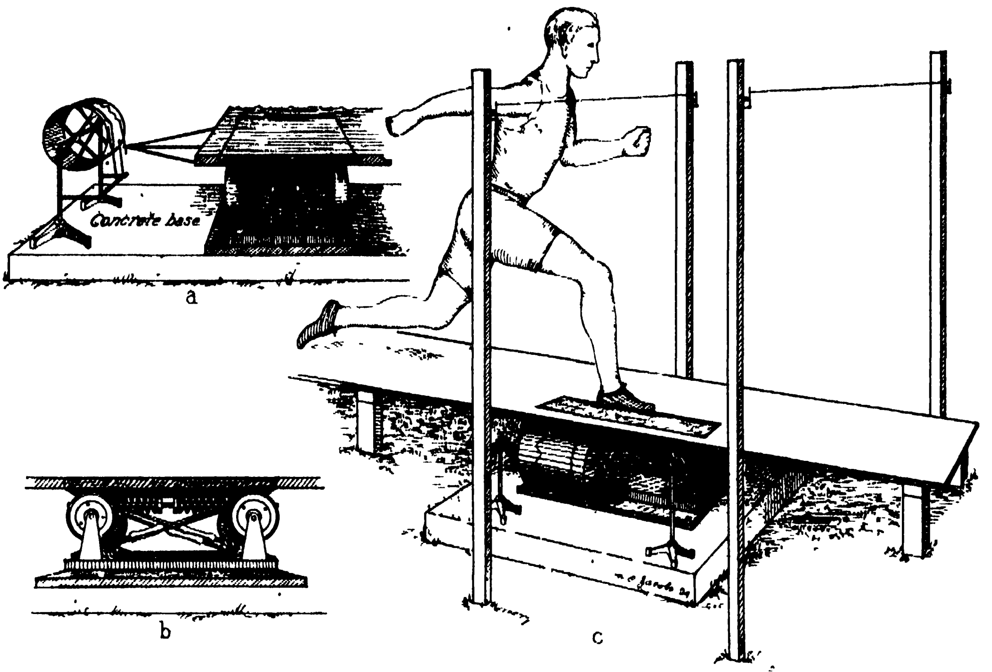


FIG. 3. MOVABLE PLATFORM IN THE RUNNING TRACK FOR THE MEASUREMENT OF THE HORIZONTAL PRESSURES EXERTED AGAINST THE GROUND BY THE FOOT. THE THREADS ACROSS THE TRACK BREAK ELECTRICAL CIRCUITS AND ARE USED FOR THE MEASUREMENT OF THE VELOCITY OF THE BODY. (FROM FENN, *Am. Jour. Physiol.*, 1930.)

greater propelling force—why the propelling force decreases from 50 kgm. at the start of a race to only 5 kgm. at top speed The reason for this is that increasing energy is needed to move the arms and legs as the speed increases, *i. e.*, to overcome the internal resistance of the parts of the machine. The leg must be moved forward quickly enough to catch the body before it falls and it must be moved backwards quickly enough so that it will not "drag." The limiting factor in running does not lie, therefore, in the external resistance, but in the *internal resistance*.

A simple experiment which any one can do at home convinces one of the difficulty of swinging the legs. During a sprint each foot touches the ground about twice in each second. Try standing on a stool and swinging one foot backwards and forwards as quickly as possible through an arc comparable to that used in running. The author's time was 15 complete swings in 7 seconds or almost exactly twice per second as in sprinting. Most of the effort of running comes from swinging the legs. The small simultaneous push given to the body is a small item in comparison and is largely done by extending the ankle joint.

The emblem of the Isle of Man represents three human legs radiating from a common center like the spokes of a wheel (Fig. 4). This might suggest that the inhabitants of this island in early times had discovered the truth of these observations concerning the work of swinging the limbs and had thus visualized a new and much more efficient method of locomotion in which the limbs could rotate in complete circles. Once endowed with the necessary kinetic energy these limbs could be left to rotate by themselves with further ad-

ditions of energy sufficient only to overcome friction in the bearings. Supposedly the time will come when only an anatomical absurdity of this kind will serve to break the world's record for the 100-yard dash at the Olympic meet. Or perhaps some acrobat will become so proficient at turning cartwheels at constant angular velocity that he can outdistance all competitors.

Thus far the argument has been fairly simple, but the next step demanded an appeal to the cinematograph and much laborious measurement and calculation before the answer was clear. Why is swinging the legs so difficult? Is it because the legs are so heavy that the force exerted by the muscles is insufficient to move them any faster or is there some physiological reason why muscles cannot pull hard against rapidly moving limbs? It turns out that both these answers are correct The problem lies in apportioning the work between these two factors. *How much of the work of leg-swinging is actually expended in working on the legs and how much in merely trying to work on them.*

We can not measure as yet how much energy a muscle expends in trying to pull against a moving limb, *i.e*., in trying to shorten rapidly enough to maintain a strong pull against it. We can, however, measure from the moving pictures how much work the muscles actually do against the limbs. For this purpose it is necessary to know the velocity with which they are moving at different times in the running cycle. This is measured by projecting the film picture by picture and measuring the angles of arms and legs. Knowing the velocity with which they are moving the kinetic energy can be calculated from the product of half the mass, *m*, by the square of the velocity v^2.

In the case of the upper and lower arms and the upper leg it is found that the energy passes through a maximum once during each forward swing and once during each backward swing. The maximum is much higher in the fore arm than in the upper arm because the former is farther removed from the shoulder joint. Likewise the kinetic energy of the lower leg, due to its double rotation around both the knee and the hip and to its greater distance from the hip, is much higher than for the upper leg. Moreover in one double step the kinetic energy developed by one lower leg passes through three maxima; one while the foot is on the ground; *i e*., during the backward swing, one when the leg is lifted and the knee flexed behind the body, and one when the leg is thrown forward. All these must be taken into account in calculating the total rate of energy expenditure (horse power) due to swinging the limbs. One of the points stressed in coaching runners is to reduce the flexion of the knee behind the body to a minimum. This reduces the height of the second of these maxima of energy and so eliminates this wasted effort.

By such calculations from the moving pictures of a series of 21 normal college undergraduates running at top speed we found an average expenditure of 1.67 horse power in accelerating the limbs with an additional 0.67 horse power in decelerating them. The former is expended in raising the velocity of the limbs to a maximum both on the forward and on the backward swings and the latter is expended in reducing this velocity again to zero, at the end of each swing. Thus if the runner can develop 6 horse power for the sprint, 2.37 horse power goes to swinging the limbs. The kinetic energy of a leg at full speed is therefore no small item. It serves to hurl footballs over far distant goal posts and if transferred to a 150 lb. man by forcible collision it would raise him bodily 5

inches into the air. Those inhabitants of the Isle of Man knew their physics well.

The argument may now be summarized as follows:

Total energy for complete recovery	13 horse power
Energy available during race	6 horse power
Air plus ground resistance	0.5 horse power
Gravity	0.1
Swinging arms and legs	2.37
Total measured as mechanical work	2.97

We are thus able to account for 50 per cent. of the energy available during the race. Even the Diesel engine is only 35 per cent. efficient. Actually the efficiency of the runner is probably even greater than 50 per cent. for we have left out of our balance sheet altogether the energy used by the heart and that which is used in contracting the muscles of the trunk and the neck to give the body the necessary rigidity. This fixation energy may be rather a large item. Here then is one of the simplest and most well defined of the many biological phenomena which, in the present state of our knowledge, seem to us beyond the realm of possibility. It is Mother Nature's challenge. Can man with all his ingenuity construct a machine which will accept chemical energy, probably derived from the breakdown in the muscle of a (recently discovered) substance phosphocreatine, and will transform this chemical energy into mechanical energy into mechanical work, without an intermediate heat stage, and with at least 50 per cent. efficiency?

How the Limbs Get Ahead of the Muscles

It has been suggested that some of the remaining 50 per cent. of the energy is spent in "trying" to pull against the rapidly moving limbs. It is not yet possible to say definitely how much this energy amounts to, but it is

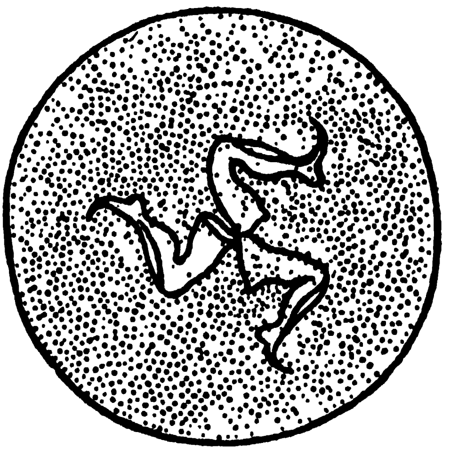


Fig. 4. Emblem of the Isle of Man. (From Webster's Dictionary, see "triskelion.") Symbolizes a method of escape from the limiting factor in running.

possible to gain a clearer idea of how difficult it is for the muscles to keep up with the limbs as they swing by determining *how rapidly the force falls off in a muscle as its speed of shortening increases.* In isolated muscles this can be measured directly as Hill has done[7] In human muscles it is possible to measure how the force which the limb can exert against some external dynamometer decreases as the speed of movement increases. This Hill has also done[8] but the results are complicated by the possibility of nervous intervention. I have recently been able to estimate this relation between tension exerted and speed of shortening in man in the following way.[9]

It is a fundamental law of physics that the acceleration with which a body moves is proportional to the forces exerted upon it. Hence if we can determine how the acceleration changes with velocity of movement we shall know how the force changes. The acceleration is the rate with which the

[7] "Muscular Activity," Chapter I.

[8] "The Maximum Work of Human Muscle and Their Most Economical Speed," A. V. Hill, *J. Physiol.* 56, 19, 1922.

[9] These results will soon be published in detail.

velocity is increasing. The velocity is determined by arranging for the arm or leg to drag a pointer along a revolving drum as it swings; then the greater the velocity the steeper the slope of the curve traced on the drum. The acceleration is the rate with which the steepness of the curve increases. The subject flexes his knee or his elbow and tries to extend it as hard as possible against a strong spring balance which measures the force developed. The limb is then suddenly released so that it is free to fly out under the influence of the tension already existing in the muscles. From the drum record which is traced as the limb flies out, the acceleration is determined. It is found that the accelerating force decreases as the velocity increases. By averaging together the records obtained in many experiments it is found that the acceleration and hence *the tension of the muscles decrease 3.2 per cent. when the velocity of shortening of the muscle is 10 per cent. of its length per second.* By the time the limb has moved 4.5 cm, sufficient time has elapsed (about 0.01 seconds) to permit some reflex relaxation of the muscles to take place. Hence this value must be calculated from the record inscribed during the first 4 or 5 centimeters of movement. After moving this distance the muscles are shortening at a rate of about 60 or 80 per cent. of their length per second and accordingly the force has dropped off 19 to 25 per cent.

From these experiments we find that the muscles lose 3.2 per cent. of their tension for an increase in their rate of shortening of 10 per cent. of their length per second. Is this sufficient to account for the difficulty observed in exerting tension against a moving limb?

From the movies the rates of flexion or extension of the knee and hip joints at every moment during the running cycle are known. By reference to anatomical papers the lengths of the lever arms of the various muscles concerned can be known and so the corresponding maximum rates of shortening of these muscles can be estimated. In this way it is found that one of the extensor muscles of the knee, the *rectus femoris,* shortens at a maximum rate of 360 per cent. of its length per second while one of the flexors of the knee, the *biceps femoris,* shortens at a maximum rate of 373 per cent. of its length per second. At these rates of shortening the force lost by the muscles would be 360/10 x 3.2 or 115 per cent. (and 119 per cent.). This approximate figure is sufficient to tell us the story. At the maximum speeds of shortening observed in the body, the muscles would be able to exert no external tension and hence could produce no further acceleration. This, therefore, is the process that sets a limit to the speed of movement.

It is necessary to ask one further question, even though no answer is forthcoming as yet. *What is it that prevents the muscles from exerting tension at these high speeds of shortening?* There would seem to be two possible answers to this question both of which involve fundamental concepts of muscle physiology.

If a muscle exerts tension against an immovable object it must spend energy continuously as long as the tension is maintained. We may describe this by saying that the muscle continuously loses tension at a certain rate and that the energy expended is necessary for the continuous redevelopment of this tension. Eight years ago, while working in Hill's laboratory in London the writer was able to show[10] that when a muscle was shortening it expended more energy, and when it was being stretched it expended less energy than when it was merely contracting without change of

[10] W. O. Fenn, "A Comparison between the Energy Liberated and the Work Performed." *Jour. Physiol.*, 58, 175, 1923.

length. We may describe this by saying that in shortening it loses tension at a greater rate and in lengthening it loses tension at a lesser rate than when stimulated at constant length. Consequently the rate of redevelopment of tension must be greater while it is shortening and less while it is lengthening than when it is of fixed length. The added necessity for redeveloping tension during shortening and the delay in the chemical reactions necessary to supply energy for this process is one of the factors which limit the tension in moving muscles. The other factor contributing to the loss of tension in shortening muscles is the viscous elastic effect studied by Hill. By this we should mean a *mechanical delay* in the development of tension due perhaps to the viscosity of the internal medium of the muscle. Certain structural rearrangements, if only of molecular dimensions, must obviously be required for the external manifestation of tension in a muscle, and these would certainly be interfered with by internal frictional resistance. The exact apportioning of the tension loss in shortening between these two factors is yet to be accomplished. Also we do not yet know how much of the total energy mobilized for the race appears directly as heat due to the inefficiency of the machine. Both of these questions are of great importance for the physiology of muscles.

In spite of these perplexities we shall still have our races and our runners. The less they know about the whys and wherefores of their remarkable machinery the better they will run and all our knowledge probably will not take one fraction of a second off their best times. But we have at least gained a better idea of why every last fraction of a second is needed.

WORD PAINTING

By Dr. C. H. BENJAMIN

ALTADENA, CALIFORNIA

Descriptive writing in prose or verse is akin to drawing and painting, in that both aim so to clothe an idea which exists in the mind of author or artist that it may be intelligible and pleasing to the public, or at least a part of the public. In either case, the success of the producer is measured by the reality and vividness which he gives to his idea in the mind of the recipient.

In the work of the artist we note two important steps: first, the drawing of the outline or structure; second, the filling in with light and shade and color, to bring out the picture in relief and give to it realism or impressionism, as the case may be. The first is more a matter of mathematics than of art, since the outline must be correct in proportion and perspective. The second is a question of artistic rendering, involving the use of the imagination and of certain tricks of light and color which shall produce the desired effect on the eye of the beholder. The great artist does not paint things as they really are but as they appear, and by a skilful manipulation of certain colors creates an atmosphere and an impression which emphasize his idea.

In like manner the author forms the skeletons of his sentences with nouns and verbs which convey the main ideas, as, "The sun shines," "The wind blows," "The man walks." To elaborate his idea and to produce a vivid impression on the mind of the reader, he embellishes his sentences with adjectives and adverbs: "The wintry sun shines feebly." "The summer wind blows fitfully." "The solitary man walks stealthily."

We may liken the qualifying words to color media, since they give life and form to otherwise vague and incomplete ideas, and as artists vary in their treatment of a theme, using different keys and different color schemes, so authors may vary their interpretations and by the use of different "word colors" produce divers effects on the minds of their readers.

The present paper is an attempt to analyze the use of qualifying words by various writers of prose and poetry and to determine, if possible, the characteristics of their various "color schemes." For the purposes of this study were chosen three English poets, Milton, Tennyson and Keats; three English prose writers, Scott, Dickens and Thackeray; three American poets, Bryant, Longfellow and Whittier, and three American prose writers, Irving, Hawthorne and Poe.

An attempt to include certain essayists, such as Addison, Carlyle and Emerson, revealed the fact that their adjectives could not be classified with those of the poets and writers of fiction, since the ideas presented by the essayists were so much more abstract in their character. You can not well compare a description of an emotion or a virtue with those of people, landscapes and buildings.

In a general way the extracts chosen for study were of two classes: (*a*) Descriptions of outdoor scenery; (*b*) descriptions of indoor scenes, including descriptions of persons present.

The selections were of various lengths, containing all the way from four hundred to three thousand words each, the total number of words from each writer being three or four thousand. A careful count was then made of the adjectives and adverbs in each selection and these modifiers were arranged in classes,

according to their significations. Considerable difficulty was experienced in determining the most rational method of classification and several plans were tried and discarded. The following method was finally chosen and, while not by any means perfect, seems to be fairly satisfactory.

(1) Adjectives of appearance or sight, including color, value (light and shade), form or outline, and texture; (2) adjectives of quantity and place, including size, number, location, motion (this division includes most of the adverbs); (3) adjectives of the senses other than sight, including sound (pleasant and unpleasant), touch, taste and smell; (4) miscellaneous, including time and abstract adjectives (pleasant, unpleasant and neutral), moral and mental qualifications.

It was at first intended to classify sound adjectives as to pitch, time, quality, etc., and to specify under touch such qualities as shape, texture and temperature, but the very limited use of the sense adjectives other than those of sight made this unnecessary. Value is used in its artistic sense to signify light and shade, brilliancy and dimness.

The adverbs are for the most part included in the subclasses of motion and time. Participles used in the sense of adjectives are included in the motion subclass. Sounds are distinguished as pleasant and unpleasant, and silence, or absence of sound, is included in the classification. Time is distinguished as long or short, past or present, and of course includes many adverbs.

All adjectives which have reference to spiritual rather than physical attributes are put in the fourth class. They are subdivided according as they indicate pleasant and good qualities or the reverse. The third subclass of neuter abstract qualities is a sort of rubbish heap for adjectives that refuse to be classified otherwise.

Selections

1. *Milton.*—For outdoor description is selected from "Paradise Lost," Book IV, lines 160 to 268, a description of Eden and of Satan's first visit. This selection mentions the approach of the fallen angel to the outer wall, the view from the Tree of Life and of the river. This was written about the year 1664, some ten or twelve years after Milton became blind. As a contrast to this are chosen "Il Penseroso" and "L'Allegro," both written about 1632, when Milton was a young man and living in his father's house. These are apostrophes to Melancholy and to Mirth respectively.

The extract from "Paradise Lost" is notable for adjectives of texture, touch and smell, and deficient relatively in those of value and sound. The last deficiency is the more remarkable when we consider that in the two earlier selections, "Il Penseroso" and "L'Allegro," adjectives denoting pleasant sounds are relatively numerous. Milton was noted as a musician, and it hardly seems that loss of sight would change his feelings in this respect.

"Il Penseroso" is strong in adjectives of value and weak in those of color, this probably due to the nature of his theme. "L'Allegro," on the other hand, is notable for its color adjectives and for those of pleasant sound; this also might have been expected. In abstract adjectives of a pleasant character, "Il Penseroso" is far in the lead of both the other selections. This may perhaps be understood when we remember that the poem tells of the pleasures of melancholy and not of its pains. It would naturally be assumed that verses written after Milton's blindness had come upon him would be deficient in the adjectives of sight and appearance. Inspection, however, shows the same number of these in the extract from "Paradise Lost" as in the two poems written in his youth.

This may be best explained in the poet's own words:

> but thou
> Revisit'st not these eyes that roll in vain
> To find thy piercing ray, but find no dawn;
> So thick a drop serene hath quenched their orbs,
> Or dim suffusion veiled. Yet not the more
> Cease I to wander where the senses haunt,
> Clear spring, or shady grove, or sunny hill
> Smit with the love of sacred song;[1]

The most noticeable peculiarity of the later poem is the unusual number of adjectives expressing smell or odor, there being twelve of these in a thousand words. When we consider the fact that this class of modifiers is rare and is entirely absent from most of the selections, this exception becomes even more noticeable. Pleasant odors made up in part for loss of light and color.

2. *Tennyson.*—The selections from Tennyson are: for outdoor life, "The Lotus Eaters" and "Mariana" of his earlier poems and an extract from "Maud" (1855), "Come into the garden, Maud"; for indoor and personal description, "The Lady of Shalott" (1832) and the prologue of "The Princess" (1847).

One notices first in these groups the comparative paucity of descriptive words in the two later poems, "Maud" and "The Princess," the percentage being smaller than in any other selections listed. On the other hand, "Mariana" and "The Lady of Shalott" contain more than the usual number of adjectives. It is to be noted, however, that this number is swelled by repetitions and refrains as is the case with the word "aweary" in the former poem.

The lack of adjectives in some of Tennyson's poems is accounted for by the fact that he frequently uses nouns in a descriptive fashion, especially color-nouns. All the extracts analyzed show a marked deficiency in sense adjectives other than those of sight. "The Lotus Eaters" and "Mariana" have an unusual number of abstract adjectives of an unpleasant sort, while in "The Princess" pleasant ones are more numerous. These differences are due to the subject rather than to any peculiarity of the diction.

A rough comparison of Tennyson with Milton indicates that the latter is more fertile in artistic and sensory adjectives, while Tennyson leads in the use of abstract and subjective modifiers.

3. *Keats.*—Two selections from Keats were analyzed, one of three hundred lines from Book I of "Endymion" for outdoor description, and one of seventeen stanzas from the "Eve of St. Agnes." The passage from "Endymion" describes the scene of the poem on the sides of Latmos.

Contrary to expectations, these proved to be less rich in adjectives than the selections from Milton or the earlier poems of Tennyson. "Endymion" is remarkable for the number of adjectives of color, texture and size, and the "Eve of St. Agnes" for those expressing pleasurable emotions. In general, it is to be expected that natural scenery will require more objective modifiers for its description, while indoor scenes, with their actors and actresses, will call for the abstract or subjective. The extract from "Endymion" contains six adjectives expressing odors and, with the exception of the extract from "Paradise Lost," takes the lead in this respect.

4. *Bryant.*—Bryant is generally considered a "nature poet" and is by some compared to Wordsworth in this regard. Several of his shorter poems were selected for comparison, the "Fountain," "The Rivulet" and "The Prairie" for the nature group, "The African Chief" and "The Damsel of Peru" for personal description. The dates of their production are unknown to the writer.

The "Fountain" contains thirty-one color adjectives in a total of about a thousand words, more than double the

[1] "Paradise Lost," Book III, lines 22–29.

proportion found in any of the other poems examined, either English or American. About one half of the modifiers in this poem belong to the artistic or sight group, an unusual ratio. "The Rivulet" and "The Prairie" have a large number of time modifiers, more than one fourth being of this character in the former poem. Both these poems are rich in descriptive words, "The Rivulet" having the largest ratio of any selection analyzed.

"The African Chief" and "The Damsel of Peru" are not remarkable as descriptive selections. The former has many unpleasant abstract modifiers and the latter a large proportion of pleasant sounds and qualities.

The five selections chosen contain no adjectives of smell and only two of taste.

5. *Longfellow.*—A selection from "Evangeline" contains about 2,500 words and was chosen to illustrate nature description, being a picture of the bayous of Louisiana, while "Lady Wentworth" and "King Robert of Sicily" supply the personal coloring. The percentage of modifiers is about the same in all three poems and compares favorably with those of the English poets. "Evangeline" was the earlier poem, written about 1847, fifteen years earlier than the other two. It is remarkable for adjectives of size, location and motion, rather than those of color or value. Over one third of the whole number of modifiers belong to the "geometric" class. Pleasant sounds are noticeable, while pleasant and unpleasant emotions are equally represented in the abstract modifiers.

In the last two selections, "King Robert" and "Lady Wentworth," the "sensory group" is almost negligible and the other three groups about normal. Pleasant adjectives largely exceed the unpleasant in "Lady Wentworth," but in "King Robert" about one fourth of the whole number of modifiers are unpleasant.

6. *Whittier.*—Extracts of 2,600 and 2,900 words, respectively, from "Snow-Bound" and from "The Preacher" serve to illustrate the Quaker poet's powers of description. The selection from "Snow-Bound" contains the picture of the farmhouse and its surroundings after the storm. The proportion of descriptive words is about the same as in Longfellow, but Whittier uses more abstract adjectives than the other poet, more than a third of the total number in each poem being of this group.

"Snow-Bound" is rich in the artistic adjectives, while in "The Preacher" those of location and motion predominate. Pleasant adjectives are more numerous than unpleasant in the former poem, but in the latter they are evenly balanced.

Comparing the averages for the six poets just considered, we find them to rank as follows in the percentage of descriptive words:

Bryant	14.1	per cent.
Milton	13.8	" "
Whittier	11.9	" "
Longfellow	11.5	" "
Keats	10.9	" "
Tennyson	9.2	" "
General average	11.9	" "

Bryant and Milton are in a class by themselves in this particular, while Tennyson is low, as before explained, because of his preference for color nouns.

Prose Writers

In order to make a fair comparison it was found necessary to confine the analysis to writers of fiction.

7. *Scott.*—"Anne of Geirstein" was chosen for outdoor description and "Ivanhoe" for indoor. The first extract narrates the approach of Arthur and his father to Geirstein and describes the Alpine scenery. In the second selection appears the description of Athelstane's banquet hall and of his household. Both descriptions are weak in

color adjectives and strong in those of form, size and texture. Geirstein is particularly rich in modifiers of location and motion. Probably this is due to the nature of the Alpine scenery portrayed. In Geirstein the greater number of abstract modifiers are unpleasant, while in Ivanhoe the reverse is true.

When we remember that the first selection is a description of wild mountain scenery and of the difficulties and dangers of travel and that the second passage portrays a feudal banquet hall and the assembly of nobles and retainers for a feast, we can easily account for this difference.

On the whole, the Geirstein is richer in adjectives, but when we find only five words of color out of a total number of 331 modifiers, in a description of natural scenery, we must conclude that the writer is not affected by color as are most of us.

8. *Dickens.*—For nature description a selection from "Old Curiosity Shop" is chosen, and for indoor life an extract from "Pickwick Papers." The first contains a part of the travels of Little Nell and her grandfather, and the second tells of the Christmas party at Wardles'. The outdoor description, in the number and character of its adjectives, corresponds closely to that of Geirstein just noticed, and the observations made concerning Scott's description will apply here. A general weakness in the sensory and artistic modifiers and a strong predominance of those pertaining to size and location and to abstract qualities characterize both.

Compare Keats or Bryant, using thirty-one color adjectives each, or Whittier using twenty-six, with the five and nine respectively of Scott and Dickens. Pickwick naturally contains a large proportion of abstract modifiers—more than half of the whole number used. The pleasant adjectives outnumber the unpleasant about two to one. Thirty adjectives of size and forty-three of time emphasize the tendency of Dickens to contrast the big and little, the old and new.

9. *Thackeray.*—Thackeray's description of Killarney in the "Irish Sketch Book" is used for one example and his account of Charles Honeyman's hermitage in "The Newcomes" for the other. Thackeray redeems himself by using no less than sixteen color adjectives in the first selection. As is the case with Dickens and Scott, the greater number of his descriptive words pertain to texture, size, location and motion, 138 out of 294 in this category. Pleasant sounds and pleasant emotions predominate.

Six adjectives of smell are found—an unusual number.

10. *Irving.*—A description of the journey from Seville to Granada in the opening chapter of "The Alhambra" has been chosen to illustrate Irving's description of natural scenery, and "Christmas Eve at Bracebridge Hall" has been selected for the indoor picture. In both these the author shows his fondness for subjective rather than objective study, nearly one half of his adjectives being of an abstract character. Adjectives of color and value are almost entirely absent, while the geometric modifiers are numerous.

In "The Alhambra" eighty-three adjectives of the pleasant and unpleasant emotions show the tendency of Irving to moralize. In both selections sensory adjectives are wanting, if we except a few descriptions of sound. In "Christmas Eve" seventy-three modifiers indicative of time as against forty-three in a similar picture by Dickens, just quoted, show that Irving has his English contemporary beaten on his own ground. In geometric words of size, number, etc., Irving also has the lead by 50 per cent. It is interesting to note that the earlier selection is richer in modifiers than one from "The Alhambra" written a dozen years later.

11. *Hawthorne.*—Hawthorne's "Mar-

ble Faun'' and his ''Mosses from an Old Manse'' were chosen for illustration. An extract was taken from the former describing the Suburban Villa in Chapter VIII, to serve for outdoor description, while the description of the Old Manse itself answers for the indoor. The emotional adjectives predominate in both descriptions, particularly those of age and time. This is natural in view of the themes treated. There is little difference between the two selections as regards the classes of modifiers used. Both are relatively weak in artistic and sensory adjectives and strong in those of size, location and motion. In this respect they are much the same as the selections from Irving just noticed. There is much of sentiment in them all and a tendency to moralize on the past.

12. *Poe.*—The description of the ''Domain of Arnheim'' from the tale of that name was chosen to illustrate Poe's power of outdoor delineation. His account of Usher and his surroundings in the ''Fall of the House of Usher'' shows the character of his indoor work. In Arnheim we find a wealth of adjectives exceeding that of any prose writer chosen and equaled only by Bryant among the poets. The larger number of these are in the first two groups, the artistic and the geometric. All these are well represented, while sensory adjectives are few in number and the abstract modifiers are only moderately represented. But ten adjectives of an unpleasant character out of a total of 281 show that Poe could be cheerful when he wished.

Usher has but few color adjectives and more of light and shade. It differs in a marked degree from Arnheim in that nearly half of the adjectives are in the emotional group and that the unpleasant ones are in the majority. Sixty-four adjectives of this last character stamp Usher as preeminently a sad tale. It is not, however, as rich in adjectives as a whole.

Comparing the six prose selections as we have those of poetry, the writers stand in the following order as regards the percentage of adjectives used:

Poe	15.1 per cent.
Hawthorne	13.7 '' ''
Dickens	12.3 '' ''
Thackeray	11.5 '' ''
Scott	11.4 '' ''
Irving	11.4 '' ''
General average	12.6 '' ''

Poe is the leader in this list, as probably was to have been expected, with Hawthorne a good second. Furthermore he leads all the authors quoted, prose writers and poets included. A comparison of the averages for writers

PERCENTAGES OF ADJECTIVES
1. Outdoor. 2. Indoor.

Name of writer		Artistic, per cent.	Geometric, per cent.	Sensory, per cent.	Abstract, per cent.
Milton	1	35	22	18	25
''	2	35	17	16	32
Tennyson	1	29	21	11	39
''	2	33	32	6	29
Keats	1	34	19	15	32
''	2	26	9	20	45
Bryant	1	30	25	14	31
''	2	29	7	23	41
Longfellow	1	21	35	13	31
''	2	30	28	7	35
Whittier	1	26	24	12	38
''	2	21	26	10	43
Scott	1	24	38	5	33
''	2	25	30	6	39
Dickens	1	18	41	7	34
''	2	15	25	8	52
Thackeray	1	18	42	9	31
''	2	18	31	8	43
Irving	1	21	30	5	44
''	2	12	33	4	51
Hawthorne	1	18	34	5	43
''	2	16	33	6	45
Poe	1	31	41	3	25
''	2	17	28	3	52

of prose and poetry shows little difference. In fact, the poets have slightly the disadvantage, their general average being 11.9 per cent. as against 12.6 per cent. for the writers of prose.

Perhaps after reading this analysis one is tempted to say, "Well, what of it?" Some literary critics are inclined to regard the use of adjectives with suspicion and to condemn those writers who are too liberal in this respect. This is a matter which we will have to leave to purists to decide. The present article shows the difference in the number and in the character of such modifiers as used by some of the leading writers of fiction and of poetry in England and in this country. It is apparent that the kind of adjective used is often due to the character of the subject, but even then the style of the author has its influence, as witness the two descriptions of a Christmas gathering by Dickens and by Irving. The most interesting comparison is that of the classes of modifiers used by the various writers, whether of color, of shade, form, texture, etc.

The accompanying table gives the percentages of each class of adjectives, *i.e.*, artistic, geometric, sensory and abstract, as compared with the whole number of modifiers in each selection. Consultation of these figures will verify statements made in the preceding text. The complete table of numbers of the various modifiers is too long to include in this paper.

SCIENCE SERVICE RADIO TALKS

PRESENTED OVER THE COLUMBIA BROADCASTING SYSTEM

THE AGE OF THE EARTH

By Professor A. C. LANE

TUFTS COLLEGE; CHAIRMAN OF THE SUBCOMMITTEE OF THE NATIONAL RESEARCH COUNCIL ON ESTIMATION OF GEOLOGIC TIME

SOME time ago when I had the pleasure of addressing the innumerable multitude of a radio audience I was rewarded by one of my hearers giving me a more correct location of a specimen to which I referred. I hope that this time one may write me as consultant in the national library in Washington and give me the author of this little poem which expresses in four lines the three main ways in which we measure time:

And still the hands around the dial creep;
And still the burning sands within the glass do fall;
And still the water clock doth drip and weep;
And that is all.

The clock dial and the hour-glass which I used vainly to shake when I practiced the piano by it are familiar, but the water clock which measured time by the slow accumulation of water, drop by drop, is now obsolete. It was a method used from classical times well through the middle ages. It may represent regular recurring paroxysms, while the first method represents the progressive, and the second the periodic methods of measuring time.

It would take many more than twelve minutes to describe the many more than twelve ways through which men have sought to gain an idea of the time it has taken to fashion the earth—by the wearing back of Niagara Falls, by the building forward of dunes and deltas, by the accumulation of salt in the sea or of oxygen in the air. But they all may be compared to the progressive slipping away of the sands of time, as in an hour-glass, or to the periodic revolutions of the hands of the clock or of the earth around the sun, or to the regularly recurrent paroxysms of the water clock. Many of the methods can not give very accurate results, for they assume, as they all must, that from the present rate of activity we can infer the past. But there is one action which seems to go on most uniformly and does not seem to be affected by any temperature or pressure likely to occur at the surface of the earth. It is that which depends on the explosion of atoms like radium.

Many of you have wrist-watches on which the figures are luminous. Some evening take a pocket lens and look at these figures. You will find that the luminosity is not a steady and quiet one but that it quivers and is made up of a shower of sparks like a bursting rocket. Of course, this must be done in the dark. In the daytime the eyes will require some minutes to grow sensitive. In the evening after dark it will probably be only a minute or two.

Each of the sparks you see represents the explosion of an atom, like the explosion of a kernel of corn in a corn-popping machine. The result of that explosion is in part a gas, the gas helium which fills our dirigibles. This corresponds to the steam given off by the pop-corn.

The atom that explodes is of some rare metal. What finally remains permanent is a substance so much like ordinary lead that it is one of the most difficult problems of physics and chem-

istry to separate it from ordinary lead. In fact we remember what Mark Twain reports of Adam at Niagara Falls that when Eve brought him a toad to name, he said, "It looks like a toad and it jumps like a toad so we will call it a toad." We will call it radio lead.

The metal best studied is uranium, which is used to make the yellow glasses that protect our eyes from glare. In the course of the change from uranium to radio lead a number of other rare elements are produced and eight atoms of helium are given off. One of these rare elements is one of the most precious things in the world, radium. Therefore much study has been given to this series of changes. Now if in a pop-corn machine we knew how fast the kernels were popping we could tell from the number that had popped how long the machine had been running. If we take of a mineral or salt that contains only about 1 per cent. of uranium a weight equal to that of paper from an eyelet hole (0.262 mg) we should get an average of about two flashes every ten seconds (98,000 flashes per gram of uranium). Since there are about eight flashes for every atom of uranium that explodes, if we divide by eight and multiply by the thirty-one million (31,556,-926) seconds in a year we get the number of atoms of lead produced each year—about a million (840,000). But even in the small quantity of uranium we have assumed there are 6,650 million million atoms, so that it takes between four and five thousand million years for the uranium to be half changed to lead, and between seventy and eighty million years for the amount of lead to reach 1 per cent.

Moreover, with regard to the exploding atoms it is found that the more rapidly they explode the further are the particles thrown, and that these may produce a discoloration or halo around the decaying mineral. These halos are often found in the rocks, and if the rate of explosion had varied much in the past the size of the halos would too, whereas the older halos are little if any greater than the recent ones. Thus the rate can not have changed much since Cambrian times. Holmes estimates that the uncertainty may be 3 per cent.

One of the sources of uranium and radium has been the yellow mineral carnotite, of Colorado. This was formed only in the last finished geological period and the proportion of lead to uranium is less than one in a hundred. Thus it is less than seventy million years old. Minerals which were formed at about the time the Appalachian Mountains were folded have more lead in proportion, something like one part in forty or fifty, and are more nearly 200 million years old. A black coaly substance known as kolm from the oldest rocks (the Cambrian) that contain well-marked fossils has the purest radio lead known. The proportion to the uranium is (.059) one to twenty, and it should be 440 million years old; and in still older rocks found before we have any well-marked signs of life we find minerals whose ratios are as high as one in ten or even one in four, indicating ages of 1,570 million years and perhaps older.

This sounds very simple and the theory is indeed quite simple. To find the rate at which uranium is changing to lead we have only to count the sparks. You can not do that with your wrist-watch. They are too abundant. But by taking a small enough quantity they can be counted. How many atoms there are in a gram of uranium is easily found from well-known chemical facts, and it is then comparatively simple from the proportion of radio lead to uranium to tell how many years ago the mineral was formed. The accuracy would depend on that of the analyses and the count.

However, there are certain ifs, as there always are in every scientific result. Science only reaches a certain probable degree of accuracy. One of the difficult

problems is to determine how much is really radio lead and how much may be lead produced from some other source. Another is what the chances are that, since the mineral formed, uranium or lead may have been leached out of it or added to it. Another question is whether the rate of change of uranium to radio lead has always been the same. Finally, where did it come from in the first place? These are questions which we can answer with a considerable degree of probability except perhaps the last one. Always, however, we find that around the enlarging area of our knowledge there is the even greater circumference of our ignorance. For every progressive and evolutionary process starts with initial conditions for which it does not account. The sands of the hour-glass would cease running down except that from time to time the hour-glass is turned over.

We can, however, say that if uranium had been changing to lead at the rate it is now changing, and if this process had been going on for not merely two or three billions of years but tens of billions of years, we should have more lead in the crust of the earth than we have at present.

In this process of atoms flying apart heat is also given off. From uranium enough is generated every hour to heat its own weight one degree Centigrade. If the whole earth had as much of this going on as granites have, it would be heating up instead of cooling down and might be getting ready to explode. However, not only is it probable that these atoms are more concentrated near the surface of the earth (since we do not find them so much in meteorites) but it has been well suggested by Joly and Holmes that just as the steam of a teakettle would periodically lift up the lid, or as a geyser periodically discharges, even so any excess of heat generated gets enough to overcome the crust resistance every twenty or thirty million years and then produces a period of volcanoes and mountain building and that thus we have alternate periods of rest and activity. Holmes counts eighteen of these since the deposit of the Swedish Kolm 440 million years ago.

It is a task for the geologist to work out these cycles and see if they have about the length (twenty-four million years) indicated. There are numerous ways of so doing. For instance, as we tell the age of a horse by the wearing down of his teeth, so we can estimate the age of mountains. The younger mountains, the Himalayas and the Rockies, are higher, and in the older mountains like the Appalachians and those around Lake Superior the folds have been beveled off until it is literally true that the valleys have been exalted and the hills laid low. Estimating the load caused by the rivers we may estimate how fast this action has been going on. It has been estimated that 15,000 feet of strata have been removed from the region of the Rockies and the Grand Canyon of the Colorado in the last two of Holmes's periods at a rate of perhaps one foot in 3,000 years. This would make the length of these two cycles forty-five to sixty million years. The thickness of the beds deposited may also be used to base an estimate.

Moreover, as we can tell the age of a tree by its rings (note the dates on the section of the big tree in front of the National Education Association building on 16th Street, Washington, D. C.) and by the thickness of the rings distinguish good years and poor years and sun-spot cycles, and as by the rings of its big trees the climatic changes of California have been studied by Ellsworth Huntington clear back to the famine that took place in the days of Elijah, even so in fossil trees and stalactites and many deposits there is a variation in their character at different seasons of the year. The clays from melting glaciers are finer

in the winter, the layers of coal and oil shale laid down in certain seasons of the year Bradley finds are richer in resins. And again, sun-spot cycles and cycles of good and bad years may be recognized. Moreover, Gilbert and Stamp and Bradley seem to have identified a banding due to a cycle of 26,000 years during which the earth changes from having its northern winter when it is nearest the sun to having it when it is farthest from the sun and back again. Thus we may estimate directly the time required to deposit certain thicknesses of beds. Bradley thus comes by an entirely different way to an estimate of the length of the last two of Holmes's periods not widely different (2 x 27,000,000 years).

Thus if we "speak to the earth" as commanded in the book of Job it will teach us that in very truth, as the Psalmist says, a thousand years are but as a day and as a watch in the night of the divine economy.

DOING SOMETHING ABOUT EARTHQUAKES

By Captain N. H. HECK

CHIEF OF THE DIVISION OF TERRESTRIAL MAGNETISM AND SEISMOLOGY, U. S. COAST AND GEODETIC SURVEY

Last July there was a severe earthquake in southern Italy which caused much damage to property and loss of life. Earthquakes and volcanoes have long been associated in the public mind, and it is, therefore, of special interest that Dr. Malladra, director of the Vesuvius Observatory, states that while his building was badly rocked by the earthquake and was saved from destruction only because the various parts were chained together, there was no volcanic activity at the time of the earthquake.

The destruction caused by this earthquake has a possible lesson for us even though the conditions are quite different. The buildings have thick walls of field stones and poor mortar and thick roofs, the thickness being intended to keep out the heat. Timber is scarce and the roof supports are weak. There is, therefore, the combination of great weight and lack of strength, an ideal arrangement for producing maximum earthquake damage. For many years destroyed houses were rebuilt in exactly the same way, to fall in the same manner in the next earthquake. This is no longer the case and the present Italian Government, through improved building codes and cooperative arrangements in rebuilding, has done much to improve the situation.

In our country there was a period of helplessness when there was even an attempt to deny the existence of earthquakes, but such an attitude is disappearing before the new possibilities which are opening up every day.

A broad gauge attack on the earthquake problem is now going on in this country, Japan and other parts of the earth. It includes practically every field of interest from interpretation of seismograph records to design of dams and other structures. With all its comprehensiveness there is one serious gap—we do not know exactly what goes on in the central region of severe earthquake. Observers tell us what they have seen, but it is well known that eye-witnesses under stress are unreliable, however honest they may be. The records left in buildings and in the earth itself are invaluable, but they do not tell us just how the results were brought about. There are almost no records of an earthquake of the greatest intensity obtained within the region of severe damage, though a few have been obtained in Japan.

The engineer is now demanding this information from the seismologist. The latter can obtain this, and he is getting ready to do it by modifying existing seismographs so that they will give the

desired record and avoid destruction unless the building containing them is destroyed. Effort is being made to secure the most complete record possible at the lowest cost. The seismologist expects that in addition to furnishing what the engineer desires he can find how earthquakes are propagated from the central region outward.

Even with instruments in operation it is going to be hard to interpret the records. All evidence, such as the way cemetery monuments fall or twist on their bases, is that the earthquake activity is complex. Persons are sure that they have seen waves roll across alluvial ground like the ground swell of the ocean and at a moderate speed, but there is no instrumental record of such waves and there is no theory to fit them.

It therefore seems that any attempt to use the records of strong motion instruments directly will fail. The problem must be approached indirectly. There are now being obtained in southern California, a region of numerous small earthquakes, complete records by sensitive instruments of all that occur. The records give the time required for the earthquake waves to travel to the instrument, yet it is difficult to locate the earthquakes with the desired accuracy. The reason is best explained by reference to so-called seismic prospecting. Somewhere in Texas, for example, a great blast is fired and the waves passing through the earth are recorded by seismographs. The different geological formations affect the path and behavior of the waves, and these effects make it possible to trace the formations.

The fact that surface layers affect the earthquake waves is an advantage in finding oil, but a detriment to earthquake study. Many observations are being made, and the results should be useful in the case of severe earthquakes.

The records of a distant station show that much of the complex activity of the central region has disappeared with distance from center, and that even though there be several centers of the shock only the greatest outburst sends energy to a distance. The simplification of the distant record gives another possible line of attack, that is, to close in on the earthquake from the outside, so to speak, and extract from records taken at a moderate distance information that is probably concealed in them. This field of study is immediately available in the records of many stations.

In addition to the earthquake waves there is good evidence from observations in Japan that the earth tilts in the central region of an earthquake during the entire period from one earthquake till the next, first in one direction and then in the other, and the claim is even made that sudden changes in the tilt just before an earthquake make it possible to predict the occurrence some time in advance. A device known as the tiltmeter has been designed and put in operation, and interesting results have already been obtained. Since Japan is a very much more active earthquake region, its tilts are probably greater than anything that would be found in the United States. However, it is quite important to study by this method regions where earthquakes have occurred in the past. An instrument of different design from the Japanese is in the process of development, but in the meantime Mr. John R. Freeman, a prominent civil engineer, has made it possible to start this study at Stanford University by bringing a tiltmeter from Japan and lending it to the institution for this study.

Since earthquakes of great severity are rare in this country and since we do not know where they may occur, it might appear that we might install instruments and then wait years for records. This can be avoided by making the instruments sensitive to a moderately strong shock, of which there is a sufficient num-

ber, and besides, regions can be selected where strong earthquakes are fairly frequent. Parts of the Imperial Valley in California will meet this requirement if history is a guide.

At best it will be some time before the desired information is in the hands of the structural engineer, and rightly, the engineer is not waiting for it. He is designing large buildings, bridges and dams as best he can for earthquake stress. There has been going on at Stanford University for several years investigation by means of a shaking platform of stresses of structures under movements resembling earthquakes, and also studies of foundation materials subjected to similar vibrations. The platform, a heavy steel structure, is set into vibration by suitable apparatus and, except in the vertical direction, is capable of closely imitating earthquake motions, provided it is known what these are. An immediate use of new information along this line is therefore indicated. Other engineering studies are being made and the elaborate work in Japan along these lines is being followed.

The activities that I have described are being carried on by a large number of organizations, among which are included the Carnegie Institution of Washington, the universities of California, the Massachusetts Institute of Technology, the U. S. Bureau of Standards and the Jesuit Seismological Association. The part which the Coast and Geodetic Survey, the branch of the government charged with seismological investigation, is being asked to play is the installation and operation of the additional instruments and the physical interpretation of the results—work that the federal government is specially qualified to undertake. The interpretation of the results in terms of principles of structural design is for other organizations.

The present state of civilization is a measure of the success with which man has dealt with his environment and fitted it to his needs. There have been many recent evidences that he has not entirely succeeded. One of the efforts of the future should be to cut the loss when nature exerts its powers which are beyond the control of man.

IN DEFENSE OF INSECTS

By Dr. FRANK E. LUTZ

CURATOR, AMERICAN MUSEUM OF NATURAL HISTORY

For hundreds of years there has been a case before the court of public opinion. It is the case of Insects *vs.* The People. From the nature of things, the insects have had nothing to say about it, and unfortunately they have had very few witnesses or active advocates on their side.

One of the charges against insects is that they destroy or appropriate to their own use about 20 per cent. of our fruit crop. In this connection I beg to present to the court the following hypothetical question.

Suppose we had never had any apples, pears, plums, peaches, oranges, strawberries or anything of that sort. Suppose, however, that a group of strangers brought us delicious samples of a great variety of such fruits and told us that they, the strangers, could make it possible for us to grow all these things. Suppose that, in return for this possibility which only they could grant, they asked that a 20 per cent. commission be paid to their relatives. Does the court think that this would be an unfair proposition? I am sure that we would be glad to accept the bargain and then, later, we would try very hard to beat the relatives out of their 20 per cent.

Although I have stated this in more

figurative language than science is apt to use, it expresses rather exactly the relation between insects and our fruit crop. There is no disputing that certain insects do immense damage, in the aggregate, to our orchards, but it is not fair to forget that we would not have any of those orchards if it had not been for other insects that carried pollen from flower to flower, enabling the plants to set the seed in connection with which the fruits develop.

This process of carrying pollen from one flower to another is called cross-pollination in contrast to self-pollination, the process by which certain flowers fertilize their seed with their own pollen. Whatever may be the possibilities of self-pollination either as a regular practice of some plants or as a last resort with others, cross-pollination is exceedingly important in the biology of the higher plants. Plants with inconspicuous flowers, such as the grasses, and trees like maples and oaks secure cross-pollination by the inefficient, wasteful method of producing vast quantities of pollen and allowing the wind to blow it over the landscape on the chance that here and there a grain will fall on another flower. Plants such as our fruit trees and berry bushes have flowers which are attractive to hundreds of kinds of native bees, to flies, to butterflies and to other insects. These insects, flying directly from flower to flower, accidentally so far as they are concerned, carry pollen on their bodies and bring about the cross-pollination which makes possible future generations of the plants visited.

If we were asked what fabrics we owe to insects most of us would quickly mention silk, but we would be likely to stop there. In the court of public opinion we have heard much about the cotton boll weevil, the pink boll worm and perhaps half a dozen other insects which injure cotton plants, but mention is rarely made of the scores of different kinds of insects busily flying from cotton flower to cotton flower carrying the pollen that enables the plant to set the seed from which we get not only one of our most important fabrics but a literally astounding lot of by-products made from cotton-seed.

Linen in all its varieties is woven from flax, the fibers of insect-pollinated plants. But the fabric which shows in the most interesting way both the complexity of biological relations and the fundamental importance of pollinating insects is wool.

Sheep may be raised exclusively on grasses, such as timothy, that are wind-pollinated, but no practical sheep-grower would try to do it. He wants clovers of some sort, and all kinds of clover, including alfalfa, are insect-pollinated. The sheep-growers of New Zealand imported red-clover seed to improve their pastures. The red clover grew, but the New Zealand sheep-men could not get any seed from their clover plants for the next year's crop because New Zealand did not have the proper insects to pollinate red clover. Bumblebees were introduced from England. These insects became established in New Zealand and are now year after year pollinating clover, making possible continuous and rich grazing for the New Zealand sheep. Just as we never miss the water till the well runs dry, so we in America have most thoughtlessly taken our clover for granted and have overlooked our debt to the native insects which have made it possible.

Of course what is true of wool is true of the mutton which it covers. Also, the same thing is true of cattle, the beef we eat, the milk, the butter, the cheese and even the leather on which we walk.

I am certain that any one who has not already done so—and that means practically every one—will be surprised at the long and important list he can draw up of things which we owe to these pollinating insects. Every important vegetable in your garden, except corn, came

directly or indirectly from a seed that was fertilized by pollen which insects carried. Also your roses and the other beautiful flowers, cultivated and wild The tobacco you smoke, if you do smoke. The coffee, tea and cocoa that you drink. These are just some of the things we owe to flower-visiting insects.

But even wind-pollinated plants must have good soil in which to grow Darwin rightly praised the soil making activities of earthworms and became their most effective press agent Risking the false impression that I think the value of earthworms is overrated, I would like to point out that ground burrowing insects are more widely—in fact, universally—distributed than are earthworms, that they are more numerous in any given locality and that they are much more active Furthermore- and this is a generally overlooked fact an additional reason for their being more effective soil-makers than earthworms is that they carry beneath the surface not only decayed leaves but rich nitrogenous plant-food such as manure and the dead bodies of animals.

Time will not permit even a sketchy continuation of this line of thought, but perhaps you are already about to ask how land plants of any kind ever existed without insects. Others have asked that question, and a part of the answer is that geological history shows that there was no extensive growth of land plants and no flowering plants at all before insects became well established on earth

Let us barely mention one or two other items in our tremendous debt to insects. Do you like trout fishing? What do you try to imitate when you tie brightly colored things to your hooks? What makes up practically the entire food of our fresh-water fishes? You know the answer. You owe your fishing to insects.

Do you enjoy the song and the sight of birds? Some of these birds are insectivorous Others are seed-eaters, but since even the seed-eaters are largely indebted to insects for the seeds they eat, you are indebted to insects for the birds themselves.

Birds are of immeasurable value to us in their beauty of sight and sound, and this value, which is real, should be a sufficient reason for their protection, allowing us to drop the sordid and, as we now know, largely fictitious reason that they stand between us and the menace of injurious insects.

Not more than half of one per cent. of the tens of thousands of kinds of insects in the United States are now seriously injurious to man or to his property, and even the best of birds are not economic entomologists distinguishing between man's insect enemies and his insect friends

Of the relatively few kinds of insects that are now our serious enemies practically all have been brought here by man from foreign countries Why are these introduced insects so injurious here although they were not particularly injurious in their native homes? Because birds kept them in check there? Not at all, but because they were kept in check by other insects that were not brought to this country with them The outstanding feature of modern economic entomology is the discovery that our greatest protection against insects which are either potentially or actively injurious is the host of other insects which are the special enemies of those that we rightly fear.

How, then, stands the case of Insects *vs* The People? Some insects are, from the view point of the people, undoubtedly guilty of great damage. It is right that we should do everything in our power to control these guilty kinds. But it is not right that we should condemn all kinds because of a few. Furthermore, it would clearly be wise for us to learn more about our insect friends and to cultivate their friendship more carefully.

THE BEGINNING OF A SNOWFLAKE

By Dr. JOHN MEAD ADAMS

DEPARTMENT OF PHYSICS, UNIVERSITY OF CALIFORNIA AT LOS ANGELES

THE lacy beauty of natural snowflakes, seen either in the originals or in the well-known photographic collections of Bentley[1] and others, has attracted the attention and held the interest of almost every one. The endless variety of detail, subordinated in most cases to the requirement of sixfold symmetry about an axis, stimulates the imagination and affords a satisfying example of diversity in unity. To the scientific inquirer, however, these pretty variants of a common pattern present some prosaic questions. What are the physical conditions which govern the making of these designs? Temperature, humidity, electric field, and the time-rates of variation of these quantities, would seem to exhaust the list of relevant circumstances, as far as conjecture can penetrate. Can the rôle of each of these be ascertained? May we hope eventually to be able to read, in a natural snowflake, the sequence of the atmospheric conditions through which it has passed, and so obtain access to a great mass of meteorological information not otherwise available? Might it become possible finally to influence the precipitation of snow on a given area? Such questions as these were the will-o'-the-wisp luring one experimenter into a field quite untilled before, though it had been open to cultivation ever since the invention of the microscope.

The precipitation of moisture, either rain or snow, from the atmosphere is believed to depend on the expansion and consequent cooling of a body of moist air, subject to the condition that no heat shall reach it from the outside during the process. This condition is always satisfied in the movements of large masses of air. The artificial production of rain by this method in the laboratory is a simple experiment—one which has been turned to notable account by C. T. R. Wilson[2] It is almost equally simple to make a laboratory snowstorm by the same method, but the product is so short-lived that all attempts to preserve it for study have been unsuccessful. In both cases there is a great tendency of the precipitated cloud to reevaporate at the end of the expansion The refinements introducted by Wilson reduced this tendency, in the rain-cloud, to relative unimportance. In the snow-cloud, however, reevaporation remains dominant in spite of all efforts to minimize it, chiefly because of the smaller density of vapor involved and the greater difference of the temperature between the expanded air and the chamber walls, which of course do not follow the rapid cooling of the contained air. This method of creating snowflakes in the laboratory was abandoned reluctantly and only after an exhaustive course of experimentation extending over eight years.

The problem was solved[3] by using a process which probably occurs more rarely in nature, but which is better adapted to laboratory conditions than the one discarded. It consists simply in mixing two streams of air, one of them dry and cooled well below the freezing temperature, the other moist and warmer. When these two streams are mingled in the correct proportion, a supersaturated atmosphere results in which precipitation occurs spontaneously, and since the heat liberated is not sufficient to raise the final temperature of the mixture to the melting point, the

[1] *Nat. Geog. Mag.*, 43, p. 103, 1923, and elsewhere.

[2] Roy. Soc. Phil. Trans. A, 189, p. 265, 1897.

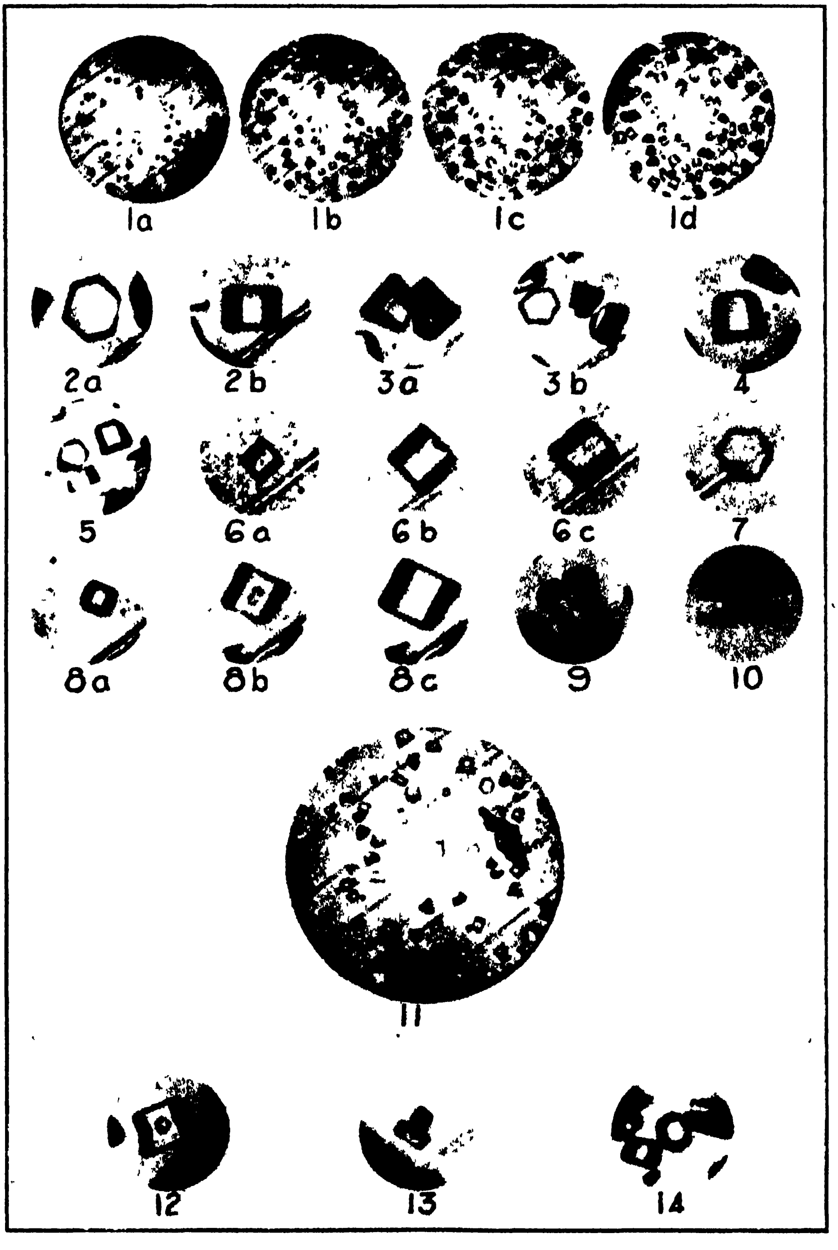
[3] Adams, *Phys. Rev.*, 35, p 113, 1930.

cloud consists of particles of ice formed directly from the vapor. To preserve these particles for study at leisure it is necessary only to bring them at once into an observation chamber which has been precooled to the temperature at which they were formed. In the comparatively stagnant air of this chamber they settle to its floor, alighting there on a glass plate ruled with lines 0.004 inch apart. Directly under this plate, and focused on its upper surface, is a microscope-objective, cooled with the chamber and protected by insulating windows from the warmth outside. The chamber is lighted from the top, and a magnified image of the ice particles, with the rulings, is formed by the objective and is brought out through the windows, to be viewed in an eye-piece or photographed directly on a film.

The earliest indication that the ice-particles have been formed is observed before they reach the plate in a reddish opalescence of the space above it. To produce this effect the particles must be of the order of 0.00004 inch in dimensions, and they are probably not manyfold larger when they arrive at the plate, since at that time the objective used (¼ inch) reveals their presence but nothing trustworthy as to their shape. Fortunately these particles have, in common with rain-drops, the property of growing at the expense of their neighbors, and it is only a matter of a few seconds until some of them have attained dimensions of the order of 0.0004 inch, and begin to show unmistakably characteristic shapes. From this point, the growth can be carried forward at will by regulating the supply of vapor, until the particles touch one another. Figs. 1*a* and 1*d* record several stages in the growth of a collection of particles. A study of such a series as this shows, first, that during growth through these stages there is no tendency whatever to develop the complications of natural snowflakes. Each particle retains its original shape while growing, and every stage is an enlarged replica of the preceding ones. This fact argues strongly for the monocrystalline character of the particles: each one builds up according to a single crystalline plan which it had from the beginning. A second conclusion which is readily drawn from these photographs relates to the simple shape which appears throughout the group, either clearly as in Figs. 2 or with accidental modifications as in Figs. 3. It is plain that the typical form of these elementary snowflakes is that of a short right hexagonal prism, the height nearly equal to the diameter of the base. The most frequent recognizable tendency to depart from this form is toward the form of Fig. 4, and this is accounted for, as will be explained below, by the twinning of two simple crystals on the basal plane. Indeed, such examples as those of Fig. 5 leave little room for doubt as to the occurrence of twinning. The reentrant angle in the crystal at the upper right and the line of demarcation in the lower one are strong evidence for this view. Observations on natural snowflakes have disclosed indications of the same process.

Twinning of this sort, in which the components are in contact on a plane perpendicular to the singular axis of the crystal, is especially common with substances in which the singular axis is polar, that is, in which the two ends of the prism are physically distinguishable from each other. In many chemicals and minerals, one end of the prism is found to be more ready to disintegrate than the other, and with them this is the preferred twinning plane. Experiment shows[4] that the ice crystal has the same sort of polarity that these substances have: one end of the prism displays a well-marked tendency to develop a pit centrally along the singular axis under conditions which are favorable to evaporation, while the other end remains flat. Figs. 6 record

[4] Adams, Roy. Soc. Proc. A, 128, p. 588, 1930.



THE BEGINNING OF A SNOWFLAKE

FIGS. 1*a*, 1*d*. FOUR STAGES IN THE GROWTH OF A COLLECTION OF ARTIFICIAL SNOWFLAKES. THE RULINGS ARE 0.004 INCH APART. FIGS. 2*a*, 2*b*. THE SIMPLEST POSSIBLE SNOWFLAKE: A RIGHT HEXAGONAL PRISM OF MONOCRYSTALLINE ICE, MEASURING ABOUT 0.001 INCH IN EACH DIMENSION. FIGS. 3*a*, 3*b*. SOME ACCIDENTAL MODIFICATIONS OF THE RIGHT HEXAGONAL PRISMS, MAGNIFIED ABOUT 250 TIMES. FIGS. 4, 5. INDICATIONS THAT TWINNING PLAYS AN IMPORTANT PART IN THE GROWTH OF SNOWFLAKES. MAGNIFICATION FROM 150 TO 250 DIAMETERS. FIGS. 6*a*, 6*b*, 6*c*. EVIDENCE THAT THE ELEMENTARY ICE CRYSTAL IS POLAR. A HEXAGONAL PRISM HAS BEEN GROWN IN SUCH A WAY AS TO DISCLOSE A DIFFERENCE BETWEEN ITS TWO BASES. MAGNIFICATION 250

the appearance of such a pit during the development of a single crystal, and Fig. 7 gives the end view of a similar pit. A crystal twinned in the manner mentioned above retains the polar property of its components and can be made to develop at the twinning plane a cavity (Figs. 8) which subsequent cooling will obliterate. In addition to this type, the photographs show many instances of twinning on the other, more stable, basal plane, as revealed by the appearance of two pits, one at each end of the twinned crystal (Fig. 9). An extreme case of this sort is shown in Fig. 10. This physical dissymmetry of ice and of the other substances already referred to raise an interesting question as to the nature of thermal conduction in them—a question which for the present must remain unanswered.

Much light may be expected to be thrown on the behavior of these elementary snowflakes when the arrangement of the atoms in the ice crystal has been fully worked out. As to the relative location of the oxygen atoms, the facts are already established. Sir Wm. Bragg[5] proposed a structure for the oxygen lattice based on certain general considerations, and his conclusions have been brilliantly verified by Barnes,[6] who used the x-ray method of structural analysis. It is not often that a crystal lattice (except the simple cubics) can be described clearly in words, without the aid of a model, but the oxygen lattice in ice admits of a simple description.

[5] "Concerning the Nature of Things," p. 174, 1925.

[6] Roy. Soc. Proc. A, 125, p. 670, 1929.

We think of a pavement of regular hexagonal tiles, and at each vertex of the hexagons we imagine an oxygen atom. Then we go over the pavement, lifting every alternate atom slightly above the general level, thus forming what Bragg calls a "puckered layer" of atoms. A second puckered layer, like the first, is prepared and is placed above the first, with the low atoms of the second layer directly above the high atoms of the first layer, and *vice versa*. The structure is continued by adding more puckered layers in the same manner. The separation of the layers, in comparison with the length of an edge of one of the original hexagons, is adjustable to agree with the axial ratio of the crystal as determined crystallographically or by the x-ray analysis. It will be seen that the structure so described has its singular axis vertical and makes no provision for any distinction between the two ends of this axis. Since the experimental evidence of the single crystals of ice requires this distinction, we must conclude that the hydrogen atoms are introduced into this oxygen lattice in some vertically unsymmetrical manner, in order to give the structure as a whole the necessary polarity. The exact disposition of the hydrogen is at present an open question, and in all probability will have to be settled by indirect methods, since it appears that in ice the hydrogen atom has given up its single electron to the oxygen and therefore has lost what little chance it had of being located by the x-ray analysis.

The study of the early forms of snowflakes has brought support to the theories

DIAMETERS. FIG. 7. AN END VIEW OF A PIT SIMILAR TO THE ONE SHOWN SIDEWISE IN FIG. 6. FIGS. 8*a*, 8*b*, 8*c*. WHEN TWINNING HAS OCCURRED ON THE BASE WHICH IS SUBJECT TO PITTING, THE FACT IS REVEALED BY A CAVITY. MAGNIFICATION 250 DIAMETERS. FIGS. 9, 10. THE CONVERSE OF FIG. 8*b*. A CRYSTAL TWINNED ON THE STABLE BASAL PLANE TENDS TO DISINTEGRATE BY PITTING AT BOTH ENDS. FIG. 11. SHOWING SEVERAL INSTANCES OF THE BEGINNING OF T-SHAPED FORMS. MAGNIFICATION 55 DIAMETERS. FIG. 12. THE T-SHAPED CRYSTALS SEEM TO DEVELOP FROM TWINS LIKE THOSE OF FIG. 8. FIGS. 13, 14. T-SHAPED CRYSTALS VIEWED SIDEWISE AND ENDWISE.

which the meteorologists[7] have advanced to explain the optical atmospheric phenomena seen in high latitudes, known as halos, sun-dogs, and the like. One of the commonest of these is the halo of 22°, which may be seen surrounding the sun or moon when the sky is slightly overcast by a snow-cloud. The effect has been attributed to the presence of 60° prisms of ice, of such a size as to be floating downward imperceptibly and of such a shape as to admit of a completely random orientation of the faces forming the refracting angle. The minimum deviation of light refracted by such a prism of ice is 22°, and it is in this direction that the refracted light is most intense. Evidently the crystals of Figs. 2 and 3 meet the requirements, since the proportions of these crystals are such as to permit them to fall equally readily in any position, and since light entering one of the six lateral faces, passing within the crystal parallel to the next face, and emerging on the third face, would be in effect passing through a 60° prism at minimum deviation. The same type of crystal is competent to account for the halo of 46°, which requires a refracting angle of 90°, the light entering on a basal plane and emerging on one of the lateral faces, or *vice versa*. The sun-dogs or mock suns of 22° are pale discs of light which are sometimes seen on either side of the sun and level with it. The accepted explanation is similar to that for the corresponding halo, except that all the 60° prisms must be falling with their refracting edges vertical To account for this uniform orientation, it was assumed that the crystals were T-shaped, since it was known that the addition of a tabular cap to a prism would tend to make it fall vertically through the air, and since occasional natural snowflakes of a T-shape or an H-shape had been observed. This hypothesis is now amply supported by Fig. 11, in which the tendency of many of the crystals to develop a cap on one end of the prism is clear. Fig. 12 shows this tendency associated with the evidence for twinning already mentioned. Finally, in Fig. 13, we have a well-developed T-form, and in Fig. 14 at the center an endwise view of the same phenomenon. It may be safely concluded that in a twinned crystal one of the components tends to develop in breadth faster than the other, though for what reason we do not yet know. In this connection it would be interesting to observe whether the sun-dogs make their appearance, as a rule, subsequently to the halo. Altogether it appears that the commonest atmospheric phenomena attributed to snowflakes require for their explanation precisely those forms of crystals which occur most commonly in the laboratory snow-cloud.

The experiments here recounted trace the growth of snowflakes from 0.0002 inch to 0.002 inch diameter. They show that at that stage of development the typical snowflake is a short right hexagonal column, about as broad as it is high, consisting sometimes of a single crystal but more often of two single crystals united by twinning on the basal plane. A well marked tendency of these twinned crystals to develop into a tabular form is disclosed. It has been proved that the two basal planes of the ice crystal are physically distinguishable, and therefore that the twin crystals are of two types. So much seems well established. The questions proposed at the beginning of this article remain for further study.

[7] Humphreys, "Physics of the Air," Pt. III, Chap. IV, 1920.

THE PROGRESS OF SCIENCE

THE RESEARCH AWARD FOR THE LIVER TREATMENT OF ANEMIA

In recognition of their discovery of a therapeutic agent for the treatment of pernicious anemia, Dr. George H. Whipple and Dr. George R Minot have been jointly awarded one of the largest prizes in America for scientific accomplishment.

Dr. Whipple, who discovered the principle of the cure, and Dr. Minot, who perfected it and applied it to human beings, each received $5,000 and a gold medal in commemoration of their work. The presentation was made by Dr. Robert A. Millikan, chairman of the executive council of the California Institute of Technology, at a gathering of scientific men and leaders in industry at the University Club in New York City.

The prize was established early last year by *The Popular Science Monthly* to increase the interest of the American people in the conquests of the laboratory and the workshop which benefit the whole community, and to focus attention upon the many scientific men and women who work to better man's control over his physical surroundings

Dr Whipple and Dr. Minot discovered the fact that a diet of liver will greatly relieve a sufferer of pernicious anemia. The two men, working independently of each other, found that the organs of certain animals and birds, such as the liver, kidney and heart, but especially the liver, contain a substance which stimulates the formation of red corpuscles and increases them in the circulating blood.

Anemia is caused by a diminution of red corpuscles and of hemoglobin, which is the coloring matter that makes them red. There are two forms of this disease, primary and secondary anemia. Secondary anemia accompanies some other disease, such as cancer and tuberculosis. Primary anemia is pernicious anemia. It is in itself a major disease and its essential cause is not known. Before Dr. Whipple and Dr. Minot made their discovery, a case of pernicious anemia was likely to result in the death of the patient.

Dr. Whipple's part in the discovery was the result of laboratory experiments. Dogs were used in the investigation, because these animals have the same blood picture as man. He bled the dogs gradually until the red blood cells were about one third the normal count, thus inducing severe anemia. He then began to experiment with various diets. A large number of foodstuffs were tested over a number of years, and it was found that liver was the most active factor in restoring red blood cells. Dr Whipple, however, did not apply his discovery to human beings, nor did he appreciate the fact that the liver treatment would prove effective in pernicious or primary anemia His dogs had secondary anemia. Primary anemia can not be induced by any known laboratory method.

It was Dr. Minot who perfected the treatment for human patients and who successfully applied it to cases of pernicious anemia His investigations showed that pernicious anemia resulted from a deficiency in the function of the bone marrow, which forms the red blood corpuscles, and that liver was a marrow builder. In 1922 he began to experiment with various diets and four years later he was able to announce that forty-five sufferers from pernicious

THE PRESENTATION OF THE AWARD

BY DR ROBERT A. MILLIKAN TO PROFESSOR GEORGE H. WHIPPLE AND PROFESSOR GEORGE R. MINOT FOR THEIR DISCOVERY AND DEVELOPMENT OF THE LIVER TREATMENT FOR ANEMIA

anemia had recovered as a result of the liver diet. Since then, Dr. Minot and his associates have succeeded in separating an effective extract of liver that may be taken in powdered form Dr. Whipple and his assistants have done the same thing, so far as the chemical extract that cures secondary anemia is concerned. Thus, it has been possible to concentrate and purify extracts that represent only three per cent. of the entire liver weight and yet contain eighty per cent. of the potency of the liver. This so-called liver fraction has been in successful use in many hospitals for more than a year.

For a number of years Dr. Whipple has been professor of pathology and dean of the School of Medicine and Dentistry at the University of Rochester Formerly he was director of the Hooper Foundation and professor of research medicine at the University of California. Dr Minot is professor of clinical medicine at Harvard Medical School and chief of the medical laboratories of the Huntington Memorial Hospital. The recipients of the prize were chosen by a committee of over twenty distinguished men of science, under the general chairmanship of Professor Collins P. Bliss, associate dean of New York University and director of The Popular Science Institute.

DR. ALOIS F. KOVARIK

PROFESSOR OF PHYSICS AT YALE UNIVERSITY, WHO IS A MEMBER OF THE NATIONAL RESEARCH COUNCIL COMMITTEE ON THE AGE OF THE EARTH. DR. KOVARIK IS SHOWN IN HIS LABORATORY WITH SOME OF HIS INSTRUMENTS USED IN ESTIMATING THE AGE OF THE EARTH BY RADIOACTIVE METHODS.

THE STATUE OF OERSTED IN COPENHAGEN

THE OERSTED CONSIDERED AS A NEW INTERNATIONAL MAGNETIC UNIT

THERE are eight electrical units, whose names by international agreement are used all over the world in electrical science and industry. Two or three of these are in such common use that their names are familiar to a large section of the general public. The two most generally known are, perhaps, the *watt* and the *volt*. The *watt*, which is the unit of power, or rate of doing work of any kind (mechanical, thermal, electrical, chemical, etc.) is named after James Watt, the Scottish scientist, inventor and engineer. James Watt revolutionized the design and construction of the steam engine, and in order to measure the power of his engines, he determined the average working rate of certain brewery horses engaged in pumping water steadily from a known depth. To a certain rate of lifting weight so derived, he gave the name *horse power*. It probably never occurred to him that his own name would be subsequently applied to an international unit of power.

In a similar manner, the *volt*, which is the unit of electric tension or electromotive force, is named after the Italian physicist Alessandro Volta, the discoverer and first inventor of the voltaic cell.

The complete series of international electrical units, as adopted up to date, is given in the accompanying table. Numbers 9 and 10 in the table are magnetic units adopted at the International Electrical Congress of Paris in 1900. As is indicated in column III, there was a certain ambiguity about the nature of the *gauss* at the time of its adoption. The proposers of the *gauss* intended it to be the unit of magnetic flux density *B*; but, by a misunderstanding, it appeared to have been adopted as the unit of magnetizing force *H*. There was subsequently a considerable amount of con-

TABLE OF ELECTRIC AND MAGNETIC UNITS

Number	Unit name	Symbol	For electric	Named after	Lived	Country	Adopted	
							Year	At
1	Volt	*E*	Tension	A. Volta	1745–1827	Italy	1881	Paris
2	Ohm	*R*	Resistance	G. S. Ohm	1778–1854	Germany	1881	Paris
3	Ampere	*I*	Current	A. M. Ampere	1775–1836	France	1881	Paris
4	Coulomb	*Q*	Quantity	C. A. Coulomb	1736–1806	France	1881	Paris
5	Farad	*C*	Capacitance	M. Faraday	1791–1867	England	1881	Paris
6	Joule	*W*	Work	J. P. Joule	1818–1889	England	1889	Paris
7	Watt	*P*	Power	J. Watt	1736–1819	Scotland	1889	Paris
8	Henry	*L*	Inductance	J. Henry	1799–1878	America	1893	Chicago
			For magnetic					
9	Maxwell	Φ	Flux	J. C. Maxwell	1831–1879	England	1900	Paris
10	Gauss	{*H*, *B*}	{Force, Flux density}	K. F. Gauss	1777–1855	Germany	1900	Paris
11	Gilbert	*F*	Magneto-motive force	W. Gilbert	1540–1603	England	1930	Oslo
12	Oersted	*H*	Force	H. C. Oersted	1777–1851	Denmark	1930	Oslo

fusion in technical literature, some writers using the gauss for the unit of H, others for the unit of B, and still others for both. The matter was further complicated by the fact that the quantity H has been used in two different senses; namely, (1) the magnetizing force due to the exciting current-turns linked with a magnetic circuit, and (2) the intensity of the magnetic field produced by the exciting current when the magnetic circuit is a vacuum or contains no magnetic material. Differences of opinion and of usage became so numerous and wide-spread that the matter was referred to the meeting of the International Electrotechnical Commission (I. E. C.) in Scandinavia last summer (June-July, 1930). At that meeting the I. E. C. decided that, for electrotechnical purposes, magnetizing force H should be regarded as essentially different from field intensity B_0 or flux density B. To the latter the unit name of *gauss* should be restricted; while the name *oersted* was adopted for the unit of magnetizing force H, by way of distinction.

Hans Christian Oersted (in Latin, Johannis Christianus Örsted was, in 1820, professor of physics in the University of Copenhagen, Denmark. In the spring of that year, he made laboratory experiments in search of some connection between magnetism and electricity. Up to that date, those two sciences were regarded as unconnected and independent. The science of electricity was well recognized, and also the science of magnetism—essentially pertaining to permanent magnets; but there was no such science as electromagnetism. He discovered that when a wire, carrying a steady electric current, was brought into the neighborhood of a horizontally suspended magnetic needle, such as the needle of a mariner's compass, the needle was deflected from its normal north-south position, and remained so deflected as long as the current flowed in the wire, or as long as the active wire remained in the needle's vicinity. This remarkable experiment, repeated in a number of different ways, was described by Oersted in a circular letter, printed in Latin, at that time an international language in considerable vogue, and addressed to a number of universities and learned societies throughout the world, bearing the date of July 21, 1820.

Ever since 1820, electricity and magnetism have been regarded as indissolubly connected. The union led shortly afterwards, through the work of other scientists, to further discoveries in electromagnetism which have profoundly affected the conduct of civilized life.

The accompanying illustration is from a photograph of a statue of Oersted, which has been erected to the memory of this distinguished Danish discoverer in a park at Copenhagen, known as the Oersted Park. It represents the discoverer standing beside a pedestal bearing a freely supported magnetic needle which he is showing to be deflected by the influence of a current-carrying loop of wire leading to a voltaic battery at his feet. The front inscription reads "Hans Christian Oersted" and the inscription at the back, as translated from the Danish, reads "Born 14th August, 1777, Died 9th March, 1851." On the occasion of its visit to Copenhagen, June 27, 1930, the visiting I. E. C. officers and delegates formally placed a suitably inscribed commemoration wreath in front of this statue.

ARTHUR E. KENNELLY

ELLWOOD HENDRICK

LATE CURATOR OF THE CHANDLER CHEMICAL MUSEUM OF COLUMBIA UNIVERSITY, WHO DIED IN HIS SIXTY-NINTH YEAR. THE PORTRAIT IS THE WORK OF AUGUSTUS VINCENT TACK.

THE LAST HEATH HEN

ON Martha's Vineyard Island off the southeastern coast of Massachusetts is the home of the lone survivor of the heath hen. The death of this individual will also mean the death of its race, and then another bird will have taken its place among the endless array of extinct forms. The numbers of heath hen have been closely followed by ornithologists and since 1908 a detailed census has been taken of the birds each year. For the first time in the history of ornithology a species has been studied and photographed in its normal environment down to the very last individual.

In early colonial times the heath hen was very abundant in favorable places from Maine to the Carolinas. The bird's habit of congregating in open fields and the ease with which it was tricked and killed by the market gunners were contributing factors to its rapid decline soon after the white man and his firearms came to America. By 1870 the heath hen was exterminated from the mainland and from that time on has been restricted to its last stronghold on Martha's Vineyard. It is remarkable that a bird subjected to all the vicissitudes of disease and enemies has survived in that limited area for over a half century. The prolongation of the life of the bird on that island has been due to the interest taken in it by the State of Massachusetts, conservation organizations, bird clubs and individuals who have done all in their power to save the bird. The State Department of Conservation has expended $70,000 and thousands more have been contributed by individuals in the unprecedented efforts to prevent the bird from being exterminated.

Many attempts were made in the past when the birds were abundant to transplant them to other favorable places on the mainland and to other islands such as Long Island, New York, one of their former strongholds. Furthermore the most experienced sportsmen and game breeders were unable to breed the birds in captivity, indicating that the heath hen was very sensitive to any radical change in its environment and that it would not yield to such methods of conservation. All the many experiments of introducing the Western Prairie Chicken, its nearest relative, to the East have likewise proved unsuccessful. Efforts to increase the numbers of the heath hen on Martha's Vineyard by the establishment of a reservation in 1908 met with temporary success. The birds increased from less than 100 to an estimated number of 2,000 in 1916. Unfortunately a destructive fire swept over the entire breeding area on May 12, 1916, which in the course of a few hours undid the work of many years The following year there were less than 150 birds remaining, and the majority of these were males. There was a slight rally in numbers during the following few years, but the birds were too far gone to overcome the surmounting uncontrollable conditions of extensive interbreeding, declining sexual vigor, the condition of excess males and, worst of all, disease. In 1920 many birds were found dead, or in a weak and helpless condition, indicating that disease was exacting its toll. The heath hen is very susceptible to poultry diseases and when domestic turkeys were introduced to the island in large numbers the dreaded disease "Blackhead" came with them. The turkeys and heath hen fed on the same fields and thus the disease was readily transmitted to the native birds. The heath hen continued to decrease in numbers, and by 1925 it was apparent that they had reached their lowest ebb in history. The Federation of the Bird Clubs of New England, Inc., then came to the front and offered to raise $2,000 annually to support additional warden

THE LAST HEATH HEN

service In spite of this splendid coöperation, the number of birds, after two years of effort on the part of all concerned, continued to decrease.

The 1927 spring census showed thirteen birds, only two of which were females. In the autumn seven birds were seen and by April, 1928, the flock dwindled to three males. During the fall of 1928 only two birds were seen and after December 8 but one was reported This bird was photographed from a blind, on April 2, 1929, at the farm of James Green, located on the state highway between Edgartown and West Tisbury. At that time it was the common expectation that the bird would step out of existence before the end of another year. It was seen regularly until May 11, 1929, but after that date it disappeared among the scrub oaks to live in seclusion, as was customary for the heath hen to do in the past, during the summer months. After the moulting season it again appeared at the Green farm in October to announce to the world that it was still alive. It was seen at irregular intervals during the winter, and after the first warm days of March it appeared daily at the traditional "booming field" at the Green farm. The State Department again placed an observation blind in the field and baited the bird for over a month in order to make it possible to study and to photograph it at close range during the period of the census.

During the springtime of former years the heath hen appeared in the open fields in the early morning hours following dawn and again in the late afternoon preceding sunset, to go through their weird and extraordinary courtship performances. This year the

lone bird generally flew out of the scrub oaks and sailed gracefully to a point near the center of the meadow. After alighting it erected its head and carefully scrutinized its surroundings, seeming to make sure that all was safe before continuing to search for food. The bird presented a pathetic figure as it stood out there all alone without any companions save the crows that had come to share the food intended for the heath hen. Though it soon started feeding it was ever on the alert for possible danger. Its eyes were much keener than those of the observer inside the blind. On several occasions the bird crouched in the grass, his colors blending so perfectly with the surroundings that he disappeared from view. A minute or two later a hawk would swoop over the field, explaining the reason for this behavior. No doubt the alertness of this individual has been an important factor in its preservation. The feeding in the open was a businesslike performance and during the time of the census was not interrupted by the booming and cackling characteristic of the courtship performance, which in former years occupied the greater part of the time of the males during the visits to the open fields. Not once did the male inflate his curious orange sacs and boom, for there was no female to admire him and no male to challenge him to such an exertion. Its spirit must be broken, but nevertheless it seems to enjoy its life and its freedom. It is in excellent health, fat and plump and in perfect plumage.

The State Department has been asked to collect and preserve this last bird for science, but from a sentimental point of view how much better it is to let this individual live in its natural environment among the scrub oaks on the sandy plains of Martha's Vineyard than it would be to put it in a cage or to mount it and have it collect dust on some museum shelf.

How long the bird will live no one can safely predict; its going is inevitable, but ornithologists, bird lovers and sportsmen the world over will have the satisfaction of knowing that all that could be done by the state, bird clubs and individuals has been done to save it from extinction. The State Department has assured us that the bird will be allowed to live, and when death comes, whether it is due to old age, disease or violence, we shall at least know that the life of the last heath hen was not wilfully snuffed out by man.—A. O. G.

THE SCIENTIFIC MONTHLY

MAY, 1931

THE ROMANCE OF DISTANCE

By Dr. OLIVER JUSTIN LEE

NORTHWESTERN UNIVERSITY

DISTANCE, in ages past so baffling to lovers and explorers that the Magic Carpet was invented long before the airplane, has become, in modern times, for the long arms of the astronomer merely the side of a simple triangle. Even to him, astronomical distances become merely significant numbers. By no known means can he picture them to himself. The person who does not have specific knowledge of the methods used experiences a loss of contact—it is almost as if the circuit of conscious confidence had been broken and an arcing jump across the break into the dark must be made under a high tension on credulity.

Now such a strain is not necessary. The fundamental methods of measurement that every one uses have developed naturally into the highest refinements used by the scientist. Keep contact. The writer will go so far as to say that any one who has mastered the equivalent of good high-school courses in elementary mathematics and physics can follow the reasoning and can actually understand the technique employed in measuring any distance, large or small, provided each step or operation in turn is clearly explained.

Finding the height of a tall object without climbing up to measure it or determining the distance to an object which is far away but visible, whether accessible or inaccessible, always implies the solving of a triangle in one way or another.

As boys we used to satisfy our curiosity about the height of trees, towers or buildings by a simple expedient. Two sticks, both as long as the known height of one of us, could usually be produced. One stick was held upright

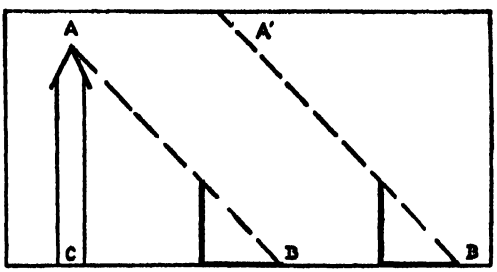


FIG. 1. MEASURING THE HEIGHT OF AN OBJECT BY THE USE OF TWO STICKS.

from one end of the other, which was laid on the ground, and both were moved toward or away from the object to be measured until the line AB just caught the peak of the object, as for example from A'B' to AB.[1] Then we knew that AC was equal to BC which we could easily measure, knowing the length of the stick, although we did not then recognize our assistant as an isosceles right triangle.

If the reader will hold one finger up at arm's length and will look at the wall or other objects in line with it while

1 The drawings for the cuts in this paper were made by Miss Beatrice Rieke.

blinking alternately with his right and his left eye, the finger will seem to jump back and forth. We call this jump parallax, which means alternation. Thousands of times every day the small triangle, formed by the distance between the centers of the pupils of the two eyes as a base line and the lines from each eye to an object as the other two sides, is interpreted by the brain as a distance and enables us to reach for objects without fumbling. Experience has sharpened this faculty until this little triangle, which has a base line of less than 3 inches, gives us an enormous power of visual orientation. For most objects it is reliable enough for ordinary purposes up to distances of a few miles.

Suppose we increase the baseline of 2⅝ inches to 4,000 miles or 96,000,000 fold. We can not make the moon "jump" back and forth with respect to the stars by winking now one eye, now the other; but, if we place one observer in Washington, D. C., and another in Valparaiso, Chile, and ask them to tell us when the north or south limbs of the moon just miss occulting certain stars, we shall find that they are making the moon "jump" a degree or more in the sky; in other words, nearly two diameters of the moon. Blink your eyes alternately at the corner of a chair or another object about 13 feet away from your eyes and it will "jump" as much as our moon does to the two observers described.

If we provide them with telescopes and micrometers to measure the displacements, which any one occupying both of these positions at one time could easily see with the naked eye, it is obvious that the triangle, composed of the distance through one side of the earth from Washington to Valparaiso, Chile, and the lines drawn from each to the center of the moon, can be solved with much accuracy. Fig. 2 shows the necessary relations. The angle AOB

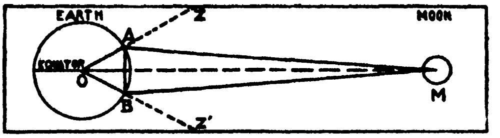


FIG. 2. MEASURING THE DISTANCE TO THE MOON.

equals the sum of the known latitudes of the two observers. Since AO and BO are known radii of the earth, we can compute the distance AB and the angles OAB and OBA. Z and Z′ are the zeniths of the two observers. The angles ZAM and Z′BM are obtained from observations. If we subtract the angles OAB and ZAM from 180°, we get the angle BAM, and similarly, the angle ABM. This solves the triangle AMB; meaning, thereby, that we can find the length of the sides AM and BM and the angle between them at M. Knowing, now, the sides OA and AM and the included angle OAM, we can find the distance OM from the center of the earth to the center of the moon, which is the fact we want. That mean distance is 238,857 miles.

In actual practice the problem is harder than it appears in the above description, but the theory as given is complete and is very simple.

This distance to the moon is not in error more than one part in ten or twenty thousand. It is as accurate as distances on the earth's surface are known from ordinary surveys. Where land is very valuable, as it is in the heart of a great city, engineers must work to an accuracy of one part in twenty to fifty thousand. The high-geared United States Coast and Geodetic Survey attains an accuracy of one part in 500,000 to 1,000,000—in the words of my colleague, Professor Berger, formerly a member of this organization, "quite easily."

Fundamental measurements of long distances on the earth are always carried out by measuring baselines and

angles and by solving all manner of triangles. Perhaps the most accurate work of this kind ever done was carried out under the direction of Colonel William Bowie in measuring the distance of 22 miles between two points on Mount San Antonio and Mount Wilson in California as a baseline for Michelson's determination of the velocity of light. The probable error is not greater than one part in 6,800,000, or about two tenths of an inch in 22 miles. The princess who could feel the presence of a pea through seven thick feather mattresses was no more sensitive than the engineers who checked and tested every tape, every instrument and every operation in this notable achievement in measurement.

This distance is known about 700 times more accurately than we know the distance from the center of the earth to the center of the sun. In other words, the latter distance may be 10,000 miles more or less than 92,870,000 miles. This is an accuracy of about one in nine thousand.

For more than 1,800 years the distance to the sun was held to be 4,800,000 miles because Ptolemy had said so. Then, near the year 1700 A. D., Cassini made a determination of this distance with the aid of Kepler's Harmonic Law and got 87,000,000 miles. In 1769, Delambre obtained 95,000,000 miles and the great Encke, in 1835, 95,370,000 miles. This was replaced about 1860 by the new value 91,000,000, which in turn gave way, in 1875, to the figure 93,000,000.

It is interesting to note the long spans of time that separate the earlier and the crowding together of the later dates. In searching out the size of the fundamental quantities in the universe, it often takes much longer to get an idea of the order of size than it does to refine that knowledge to a satisfactory accuracy. To suggest a problem from another field in which we now find ourselves in the first stages of quantitative measurement, we may say that it will probably take psychologists a much longer time to find objective means of measuring human personality, even approximately, than it will thereafter require to develop means of recording fine distinctions by such measures.

In almost all secondary types of measurement the reverse is true. For example, any one can measure the length of a short steel rod and give it correctly to the one fiftieth of an inch. An accuracy of one one millionth of an inch is only attained at the expense of much time and money.

Astronomers of ancient time thought that all the stars were located at the same distance from the earth and just outside of Saturn, which was the outermost planet known to them. They could not conceive of space being wasted between Saturn and the stars. Had they known the distance to Saturn and the amount of matter in the solar system, which they did not, they would have seen that even this relatively compact little system is mostly waste space. If we should weigh all the material in the sun and the planets, excluding Pluto, the total would be close to 1.66×10^{27} tons. These bodies move so that they may always be found inside of a thin circular disk of space 174,000,000 miles thick and less than 6,000,000,000 miles across. Suppose we pulverize the material and scatter it uniformly inside this disk. Every cubic mile of space will contain about 675 pounds of dust, which would hardly cause a perceptible haze.

Interstellar space is almost inconceivably vacant. Sir Arthur Stanley Eddington estimates that, with all the billions of gigantic stars, all the possible planets, all the visible and dark nebulae, space is so extensive that the average density in the universe is 10^{-28}. This

means that one cubic inch of water or its equivalent of any other substance has 10^{28} cubic inches, or forty trillion cubic miles, to play around in. Waste space indeed!

All such figures involve knowledge of the amount of matter in the universe and its distribution. Our concern is with the distances of stars and other celestial objects and again we start with the lowly triangle.

In Fig. 3 the earth is shown in two positions in its orbit, about six months

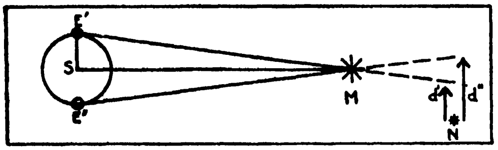


FIG. 3. THE PARALLAX OF A STAR WITH RESPECT TO DISTANT STARS LIKE N.

apart. A star M is displaced angular distances d′ and d″ in relation to a comparison star N. Half of this angle, E′MS, is called the parallax of the star M with respect to such stars as N. The base line E′S is known to be 93,000,000 miles, and hence by trigonometry the distance to the star, SM, becomes known. The measurement of the angle E′ME″ is the difficult part of the problem. For the last three decades it has been done almost exclusively by photography. The distances of over 3,000 stars have been determined in this fashion and a great many of these parallaxes have been measured at two or more observatories. In general the agreement is as close as can be expected. It must be remembered that even for the nearest star, Alpha Centauri, the displacement measured, as in Fig. 3, is just equal to the displacement of an object 4.1 miles away when viewed from the two edges of a silver quarter dollar set on its edge facing the object.

The relative parallax of a star M, so determined, is always a little too small, because the comparison stars themselves, like N, are displaced slightly with respect to the background infinitely far away.

Fig. 4 illustrates this point. Infinity

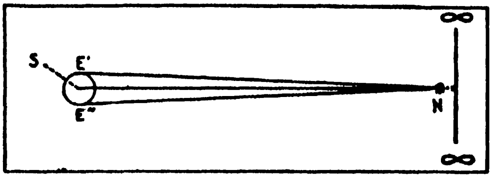


FIG. 4. ABSOLUTE PARALLAX OF STARS LIKE N.

is here taken in its mathematical meaning as a distance greater than any distance we may choose. In actual practice we use the word with a great variety of meanings. The ordinary brand of camera carries a scale for setting the focus which may have numbers up to fifty or a hundred stenciled on it. Beyond 100 feet we say, rather loosely to be sure, that the focus is infinite, meaning thereby that the change in the focus for greater distances is not appreciable. In the case in Fig. 4 infinity may be taken as ten or a hundred times farther away than the greatest distance we can measure.

The reader may say, "How can you determine the displacement of the star N with respect to the background of infinity you have assumed, and if you can not, then how can you know what small positive correction to apply to the relative parallax of M to get its real distance?" The answer is, we can not, directly. And, for the nearest fifty or one hundred stars it does not much matter, since the correction, E′NS in Fig. 4, or the "reduction to absolute" as it is called, is only a small fraction of the whole parallax of such near stars.

When we deal with more distant stars, as we are now doing, it becomes of the greatest importance.

If we wish to deal statistically with the distribution in space of stars whose real parallaxes are of the same order of size as the reduction to absolute, we must

find some way of determining this quantity. In other words, what can we do when the star under investigation is as far away as the comparison star?

Before discussing the methods used to find the distances of these faint comparison stars, let us consider briefly the progress in determining stellar parallaxes, which has been called the most delicate operation in the whole range of practical astronomy. Up to about 1600 A. D. the vaguest ideas were held about the distances to the stars. At that time Tycho Brahe tried to test the truth of the heliocentric theory of the solar system by observing the alternation in positions of stars due to the earth's orbital displacement. In spite of the increased refinement which he developed in observational astronomy, he could get no displacement of stars and concluded that Copernicus was wrong. Attempts to measure the parallaxes of stars were made time and again but without success until Bessel, in 1838, in Germany, measured the parallax of 61 Cygni and Henderson, in 1839, in South Africa got the distance of Alpha Centauri.

Up to 1888 the parallaxes of twenty-five stars had been measured. In 1901 there were fifty-eight published values. In 1924 Schlesinger discussed the parallaxes of 1,870 stars, many of which had been measured by two or more different observers. It is safe to say that a thousand more parallax determinations have been made up to the present time.

During the last 25 years many attempts have been made to correlate stellar parallaxes with other quantities, such as brightness or magnitude of the stars, or with magnitude and proper motion, which is the very minute change of a star's position in the sky, or with the magnitude, proper motion and angular distance from the plane of the Milky Way. The idea is that if we could get such a correlation established for brighter stars, we might possibly expect it to hold for fainter stars and hence we could, by an extrapolation, determine the "reduction to absolute."

The apparent brightness of stars alone is a poor criterion of distance. We know that one star may in extreme cases actually be 100,000,000 times brighter than another, for we can determine the absolute magnitude of stars as soon as we know their distances. Mathematically, "absolute magnitude" is defined as the apparent magnitude plus five plus five times the logarithm of the parallax in fractions of a second of arc, that is,

$$M = m + 5 + 5 \log \pi.$$

In a sense this is an arbitrary definition, but no more so than our definition of a yard or a meter as the length of certain carefully protected metal bars in the keeping of the English and French governments. The absolute magnitudes of stars are the luminosities which they would have if we brought them, one by one, to such a fixed distance from us that they would all have the same parallax, 0.″1. In other words, we bring the stars up to a fence, which is 32.6 light years or about nineteen trillion miles away, and then compare their real luminosities. Until we know its distance, we can not tell whether we are looking at a faint star which is small and quite near to us or one that is very luminous and very far away.

Of the seventeen stars so far known to be nearest to us only six are visible to the naked eye, and the distances of more than one thousand naked-eye stars have been measured.

Proper motion alone is a better criterion of distance provided, first, that we have this quantity for a large number of stars; second, that there be available measured parallaxes, determined by our familiar triangle, for a sufficient number of faint stars to establish strong correlations between distance and apparent motion; third, that we determine

these correspondences independently for rather small portions of the sky and do not try to generalize over the whole celestial sphere with one formula.

Unless such conditions are fulfilled, it is necessary to make assumptions about the symmetry or other characteristics of stellar distribution. The resulting picture may be beautiful, mathematically, and yet fail to represent nature. It is important for an astronomer to be a naturalist as well as a mathematician.

The sun moves, like everything else in the universe, so far as we know, and, *with respect to the brighter stars,* its motion is toward a point between the constellations Lyra and Hercules, at a velocity of twelve miles a second.

Stars observed at right angles to this line of motion will seem to move backwards in the sky, systematically—nearby stars much and distant stars less. Stars which are situated near the point toward which the sun is moving, the solar apex, or at the opposite point, the antapex, will not be affected.

This apparent movement of the stars is called parallactic motion and the yearly amount of motion of a star, located at right angles to the line of the sun's track, is called its secular parallax.

It is true that much valuable information about the relative distances of stars has been gotten in the past by considering the parallactic motions and the brightness of stars and their angular distance from the Milky Way. But the key to the whole process, if we wish to find the real distribution of stars in space, is the solution of our triangle. Actually the motions that have to be considered are very complicated. Suppose we enter leisurely into a large moving aggregation of people such as a crowd at a state fair near the noon hour. In general the persons at our sides will seem to move backward with respect to us. But there are large numbers of people moving, streamlike, toward the gate to go home. Other large groups are drifting toward refreshment stands on the grounds. Here is a group of adults moving athwart our course in orderly procession. There is a family group, also in general motion toward some point, but the individuals are shifting their positions in the group, perhaps more or less about the father as the center of gravity. And all through the large crowd, individuals are running at high speed in many directions or standing still as if to take their bearings or to converse. From tubular samples of space given him by his telescope, let us say on a photographic plate, the astronomer must decipher the component motions, distances and speeds of stars from a composite flux which is in no wise simpler to untangle than the case described above except that he has more time in which to do it.

Within the last fifteen years a most interesting method has been developed by which the distances of stars may be gotten by correlation with the relative intensities of lines in their spectra. The method was organized by Adams and some of his colleagues at Mount Wilson.

Very careful study has revealed that the ratio of the intensities of selected pairs of lines in the spectrum of a giant star differs greatly from the ratio for the same lines in a dwarf star. Suppose we compute the absolute magnitudes of all the stars of spectral type K, say like Arcturus, *for which we have gotten the parallax by the rigorous triangle method,* and measure the ratio of intensities of two lines in the spectra of each. We can then make a diagram like the one below and draw a smooth curve through the points. Obviously, we may now observe the ratio of these lines in the spectrum of a star of unknown distance —let us say it is + 1.0—enter the dia-

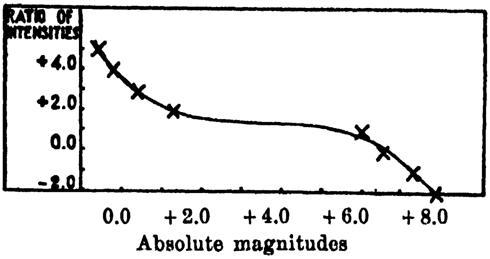


FIG. 5. RELATION BETWEEN ACTUAL LUMINOSITIES OF STARS AND THE INTENSITIES OF LINES IN THEIR SPECTRA.

gram at the left and where the horizontal line strikes the curve go down to the lowest line and read off the absolute magnitude, which might be 5.5. By reversing the process for finding the absolute magnitude when we know the real parallax, we may now find the real parallax because we know the absolute magnitude. This method of finding distances of stars, which is much used at present, depends entirely upon the method of the triangle.

Up to a dozen years ago we had only the most sketchy notion of the distances to such celestial objects as spiral nebulae and globular clusters. This situation has changed.

The two Magellanic Clouds, so called because they were noticed by the Portuguese navigator, Magellan, in 1520, are great aggregations of stars quite detached from the Milky Way. Each contains large numbers of stars that vary in light, and since the variation is such as has been observed in the northern star delta Cephei, they are called Cepheids. In 1908 Miss Henrietta Leavitt, of Harvard, who was studying these variables in the Smaller Magellanic Cloud, called attention to the fact that the brighter the star, the longer it took to complete a cycle of variation in light.

Since all the stars in this isolated cloud group must be approximately at the same distance from us, their difference in brightness must indicate differences in actual luminosity, unconfused by the effect of varying distances. Their apparent magnitudes are absolute magnitudes in their own system, and Miss Leavitt had discovered, therefore, a direct correlation between these absolute magnitudes and the periods of variation in light, which are easily observed.

Now Cepheids are a clannish breed of stars. They are much alike, wherever found. Nearly all border on gianthood. The variation in light is rather small but very regular. A considerable number are known in the Milky Way outside of clusters.

If in some manner we can determine the distances of some of these bright, nearer Cepheids and therefore, their absolute magnitudes as first defined on page 389, and if we can assume that all Cepheids, whether in our system or in distant clusters, are stars in the same stage of development, we have a means of finding the distances to such stars in nebulae and clusters and therefore the distances of these objects themselves.

Remembering that all we could hope for at first was to get some idea of the order of these distances, this is just what Shapley did.

By a study of the parallactic motions of eleven bright Cepheids in our own Milky Way system of stars, for six of which there also existed direct parallax determinations, he was able to assemble data which we shall present as a graph.

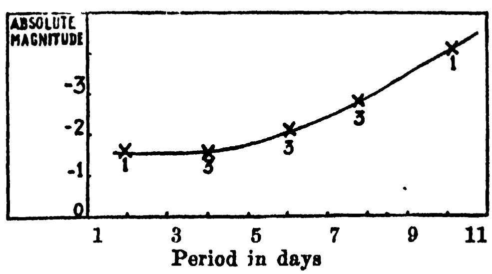


FIG. 6. RELATION OF ACTUAL LUMINOSITIES OF CEPHEID VARIABLES AND THEIR PERIODS OF VARIATION.

The subscripts give the number of stars entering into each plotted point. The relations indicated in this graph have been further confirmed by Shapley in later investigations, and the curve given above has been smoothed and extended greatly. Having determined the period of Cepheid variables in the very distant spiral nebulae and globular clusters of stars, we may use them with the graph to get the absolute magnitude and hence, by the aid of the formula given above, the parallax or distance may be computed.

If we remind ourselves that light takes 500 seconds or 8⅓ minutes to get here from the sun; 5 hours and 33 minutes from Pluto; 4.3 years from the nearest star; then we are only slightly prepared to learn that the distance to the Smaller Magellanic Cloud, which Miss Leavitt studied, is 105,000 light years; to the naked-eye globular cluster in Hercules, 33,000 light years; and to the spiral nebula, Messier 33, 850,000 light years.

Should you after reading these figures keep them in mind while you get into your car and set a clip of 60 miles an hour on a wide road with little traffic, you would find your car and yourself rooted to a point in interstellar space, unable even in your whole lifetime to move so much as across the width of a cosmic punctuation mark, the period.

While the extreme distances given are not arrived at by direct measurement, they rest finally upon the solution of the triangle we have discussed earlier. So great is the satisfaction in having evolved a method which promises to yield even the order of distances to these objects, that we are not now concerned whether the distances found are 50 per cent. too small or too great.

This is certain, the universe was built on a large scale. It is no less certain that the human mind is capable of finding out what the physical organization of the universe is like. We might suggest 10^4 years as a suitable period of future time in which to find out where the universe began, where it is going, and when and how it will get there. Complete reports before the end of some such period of further study should be considered premature.

THE NATIONAL OVERWEIGHT

By Dr. ALONZO E. TAYLOR
STANFORD UNIVERSITY

Overweight is a term concerning which there need be no quibbling. In adults there is a definable relation between weight and body height. This ratio varies with type. A stout Swede differs from a stout Italian; but the tourist has no difficulty in recognizing fat persons in Sweden and fat persons in Italy. The relation of body weight to body height is readily expressed in an average, with an allowance for individual variations. Enlistment records of armies furnish good standards for men in the third decade of life. Life insurance records furnish good standards for men and women after thirty. The standards are different for men and women. All demographic standards must be applied with common sense and discrimination, and this holds for overweight and underweight of the human body. If a man of a certain height, whose weight according to the standard tables ought to be 190 pounds, weighs 200 or 180 pounds, the variation would lead to little concern, statistically or medically. But if his weight were 220 or 160 pounds, the figure would indicate significant overweight or underweight.

Further, the definition is not merely static, it is also dynamic—to use formal phrases applied to a commonplace topic. Overweight is likely to be attended with lowering of facility in body movements, a reduction for the individual and for the age. The stout man feels himself encumbered; he handles himself (at his occupation or at a sport) with less than accustomed dexterity. The stout woman feels herself less disposed to physical activity, her household tasks are done less dexterously, her dancing falls off. Stout persons usually feel, and look, less "fit."

When the two criteria are combined, overweight means weighing more than one should for one's height and age, with the consciousness of encumbrance. The sensations support the scales. The disability of overweight must be distinguished from the disability of advancing age; but this is usually not difficult except for individuals who are trying to hide their overweight from themselves.

It is commonly believed that overweight, within limits, is an asset in childhood and adolescence, the expression of high nutrition promoting resistance to disease. After thirty, however, and especially after fifty, overweight is unquestionably no asset but a liability. A pronounced degree of overweight, which is obesity, brings diseases in its train, of which diabetes is the striking illustration. It is not generally realized how large a proportion of those with overweight after fifty approach obesity. Medical experience and life insurance analysis of sickness and death make it clear that even moderate overweight imposes a burden on the organs of circulation. Diseases of the circulation represent the outstanding cause of death after forty. Without going into details, it is accepted that overweight increases the incidence of disease and raises the death-rate.

The expectation of life is increasing, but the span of life is not being extended. The increasing proportion of men and women who pass fifty must give more than casual attention to the trend of body weight. Bathroom scales are at once a guide and an inspiration.

It is certain, other things equal, that persons without overweight, perhaps even those with underweight, pass through middle age towards old age more comfortably than those with overweight. If any one will make a census of persons in his acquaintance over seventy years of age, and divide them into a spare group and a stout group, one will learn how much larger is the proportion of thin persons in old age. Exceptions exist, of course; but no man over sixty can expect to carry around forty or fifty pounds of excess fat without paying for the effort.

The body weight at any time after childhood (excluding disease) represents the balance of three factors: the amount of food ingested, the amount of body heat lost by radiation, and the amount of muscular work (and exercise) done. It is best to consider these in the reverse order.

Work and Food Requirement

When the human body converts the stored energy of a foodstuff into work, this entails a combustion. But the mechanical efficiency of the process is incomplete: about three fourths of the energy is dissipated as heat, around a fourth is recovered as work. The heat remains in the body, to be disposed of according to circumstances. As every one knows, hard work entails heavy eating, sedentary occupations are supported on a light diet. The amount of daily muscular work being done by the average American man and woman is declining sensibly every year. This is the consequence of the mechanization of society. Machines take the place of work animals and of manual workers. More and more, men become guiders of machines, fewer men function as manual workers. Hard work gives way to moderate work, moderate work gives way to light work, the average gainful occupation approaches more and more the status of a sedentary vocation.

The progress is in the same direction in the home, though mechanically not to the same extent. Every labor-saving contrivance introduced into the home—running water, central heating, electric light, improvements in fuels and in stoves, power-driven washing machines, dish-washers and vacuum cleaners, electric irons and so on—has reduced the manual labor of household occupations. The net result is reduction of muscular effort as well as of fatigue.

Improvements in transportation, communications and business methods have reduced the bodily labors of living. We do not need to go for or deliver the news; it comes to us. The efforts attending many occupations are reduced by perfection of transportation and of business methods, the latter an inadequately recognized element. The automobile has enormously reduced the average annual exertion of walking. Both city and country life can now be replanned, because people ride to their work instead of walking to it.

Against these numerous items of saving of exertion only one factor operates in the opposite direction—increase in sports. But the counter-effect is small; the golf courses, tennis courts, baseball and football fields (even without considering the decline of hiking) are not a significant counter-weight to the mechanization of gainful occupations. Furthermore, apart from golf the sports are largely the exercises of youth. As to golf, the physical exercise of the game, so far as the average player is concerned, is exaggerated; probably the average player, in response to the appetite aroused by the game, overeats enough to make up for the energy expended.

The cumulative result upon the food requirements of the various elements in the mechanization of society is highly significant. It can not be measured; but when one recalls that a man doing extreme work requires six to eight thou-

sand calories, hard work four to five thousand calories, light work three to four thousand calories and sedentary occupations less than three thousand calories per day, the extent of the lowering of food requirements consequent on mechanization becomes apparent.

Climate and Food Requirement

Considering now the second factor, the radiation of body heat, we find that here also a progressive saving has been taking place. Warm-blooded animals keep their body temperature quite constant. The lower the external temperature and the heavier the radiation, the larger the food requirement to keep the body warm. With each decade a smaller proportion of men and women work in occupations exposed to cold. Dwellings, factories and office buildings are being better heated. The food required to keep the average body warm is being gradually and significantly reduced.

The Gross Food Requirement

Considering now the first factor, the amount of food ingested, we find that this depends primarily on the requirement for sustenance and secondarily on the requirements for support of work and body heat. The average requirement of the adult at rest in a room temperature of around 90° F. is considerably less than two thousand calories per day. This includes all the protein, fat and carbohydrate; all the nutritional elements needed to maintain repair and upkeep of the tissues. Food must be ingested in excess of this amount to keep the body warm in a colder surrounding temperature and to maintain muscular activities. Under these circumstances, the average per capita intake of food per year in terms of calories has probably depended more on work and exposure than on the basal requirements of the body. With these two factors declining, as indicated above, the average amount of food required per person per day is substantially lowered.

Food Intake and Overweight

What has this to do with overweight? It has to do with overweight because we do not reduce the intake of food as we reduce muscular work and exposure. As muscular work and exposure decline, hunger and appetite do not decline correspondingly and we tend to put on weight. The food ingested in excess of daily requirements is largely converted into and stored as fat.

It is frequently suggested that instinct is a safe guide for eating. This pleasant homily is unsound, so far as overweight is concerned, because animal instinct runs in the direction of overweight. Hibernating animals gorge themselves during the summer in order to have fat enough, when they "hole in," to carry them through the winter. The winter is the lean season for herbivorous animals; instinct leads them to enter the winter as fat as possible, as forage is restricted. Winter is also the lean season for carnivorous animals. In general, in the temperate and polar zones, spring weights of wild animals are lower than fall weights.

This instinct holds in domesticated animals and is utilized in raising live stock for the market. On the farm animals are now commonly fed with the use of contraptions called "self-feeders," which leave the animals free to choose between different feeds and to limit themselves, or stuff themselves, according to impulse. The razorback hog has the same instinct as the stall-fed pig, but the latter is not forced to waste his energy hunting for feed. The system of "self-feeding" works because it lies in the nature of the beast to get fat, and instinct guides his feeding in the direction of overweight.

This instinct holds for human beings,

to the extent that instinct holds for eating at all. Most adults tend to eat too much, relative to their requirements. In this we are aided by the wide choice of foodstuffs available to us, by improvements in the art of cooking, and by the added attraction contributed to the repast by tempting service, esthetic surroundings and social amenities. In our modern life, psychological appetite has as much scope as (or more than) physiological hunger. We have a number of effective motives for eating aside from physiological need, and they are operative a great deal of the time.

Overeating, relative to need, is the major cause of overweight. There are persons who overeat and remain thin; there are also persons who diet and grow fat. But such persons are few in number, the rare exceptions, abnormal, or at least anomalous. After all, human beings are animals and animal husbandry is founded on the demonstrated doctrine that feed makes fat, and fat can not be gotten without feed.

The easiest way of avoiding ingestion in excess of requirements is to use bulky foodstuffs with low caloric content instead of concentrated foodstuffs with high caloric content. It is possible to lose weight on a full stomach three times a day; it is possible to gain weight on a diet which does not fill the stomach once a day. It is in this respect that fruits and vegetables are attractive; they are invaluable for vitamins and mineral elements, but they are also valuable in satisfying hunger and appetite without promoting overweight.

There is an esthetic as well as a physiology of overweight. Overweight consists largely of fat, with its attendant water. Fat has a way of accumulating in places where it is really not wanted and in regions where it is conspicuous. An artist could distribute thirty or forty pounds of fatty tissue over the frame of a six-foot man with retention of pleasing lines; but nature fails to do so. There is no accounting for tastes. The inhabitants of those countries where obesity is sought as a matter of personal appearance (as in the Levant and in the Orient) could doubtless give reasons for their preference; but it can hold little gratification for an elderly American gentleman to look like a Brownie. What makes obesity less abhorrent to men in this country is in part the fact that masculine raiment is so nondescript in appearance that it does not look much worse on a fat man than on a thin one. It is perhaps not to be wondered at that obesity becomes a sign of distinction in a country so poverty-stricken that undernutrition is the rule.

Economic Considerations

One of the outstanding features of the modern social economy is the prominence of services contrasted with goods. Among the goods, the foodstuffs have declined in prominence, contrasted with other goods. Sustenance of the body makes relatively lower claims than formerly. With increased national income has resulted a subordination of revictualment which is not adequately appreciated. Evidence from census sources and from surveys of distribution suggest that the outlay of the American people to cover the food supply is not much over a fourth of the national income. Indeed it is coming to be realized that the inclusive outlay for the automobile is almost as much. Stated baldly, this implies that the automobile costs the statistical family as much as the food supply, and together the two take up about half of the national income. For the subject in hand, the importance of this lies in the relation between burden of subsistence and level of subsistence.

When a country is poor, undernutrition is likely to be prevalent. When from half to two thirds of the national

income must be expended for the food supply, it is likely that the average plane of nutrition will be such as to entail underweight. Pressure of population on food supply tends toward underweight. When, on the contrary, a country is rich, undernutrition is likely to be of only incidental occurrence. The foodstuff that was once a luxury becomes a comfort, the foodstuff that was once a comfort becomes a necessity. When food supplies are freely abundant and only a fourth of the national income needs to be spent for foodstuffs, a high level of nutrition is likely to be maintained. A high level of nutrition tends toward overweight. Whenever it is easy to be fully nourished, it becomes easy to be overnourished. Instead of being comparable with the razorback hog, which has to hustle and root for his feed and keeps thin, we are comparable with the stall-fed pig, which chooses his feed out of self-feeders and grows fat. It is often said that prosperity makes the population soft; it is equally true that it makes the population fat. The White House Conference on Child Health has made it evident that we have a relatively high incidence of defects attributable directly or indirectly to faulty nutrition. But clearly this is due for the most part to ignorance. The ignorance which is likely in children to lead to undernutrition is likely in those past middle life to lead to overweight. In short, in the national sense, sustenance of adults has ceased to be a problem; instead, to a significant extent, oversustenance of adults becomes a problem.

Summary

Let us now summarize the argument. There are instinctive impulses and physiological tendencies in the direction of overweight, which will prevail unless restrained or counteracted. We live in economic circumstances which permit an easy functioning of the influences making for overweight. The national income is rising. The proportion of the national income required to cover the retail cost of the food supply is relatively small. Foodstuffs are available in extraordinary variety and profusion. The per capita food requirement is declining. Economic restraint on eating is lacking except in the poorest classes. Under these circumstances, the probability of average overweight is increasing. Unless restrained, a decade hence the average overweight of people over forty will be significantly higher than it is to-day; the effect of overweight upon incidence of disease and upon the death-rate will become more conspicuous. The solution does not lie in sports or physical exercise. Four factors are to be looked forward to as restraining influences: education in nutrition, medical precept, life insurance admonition and style. And the greatest of these, probably, is style.

THE FILTERABLE VIRUSES[1]

By Dr. EARL B. McKINLEY

DIRECTOR OF THE SCHOOL OF TROPICAL MEDICINE, THE UNIVERSITY OF PORTO RICO, UNDER THE AUSPICES OF COLUMBIA UNIVERSITY

THE field of the filterable viruses is an ever-widening one which, particularly during the last decade, has commanded the attention of investigators in practically all parts of the world. Within recent years investigations in this field have become so extensive that a large number of scientific journals and publications contain in each issue papers or at least some reference concerning interesting phases of this subject. Various text-books of recent edition have included a section on the filterable viruses and two volumes have been published within the last two years which have attempted to treat the subject in an exhaustive manner. It seems altogether fitting then for scientific publications of general interests to publish periodic reviews of such subjects as the filterable viruses, particularly since many of these, the filterable virus field being a notable example, are changing and developing with kaleidoscopic rapidity. In a very limited space the author will attempt a brief picture of this fascinating subject.

No one has as yet offered a suitable definition of a filterable virus. Not all filterable viruses are ultramicroscopic; hence the latter term is not precisely synonymous with the former, although it is decidedly a more definitive one. The term filterable virus has come into general use chiefly because most of these agents have been shown to pass through the pores of porcelain or diatomaceous earth filters. The term is therefore relative and only in a general way indicates size, for actual filtration of these agents depends to a large degree upon several other factors, such as the electrical charge carried by the particle and the substance of which the filter is made, the viscosity of the material being filtered, its hydrogen concentration, to some extent, and the amount of positive or negative pressure which is employed in carrying out the filtration operation. No doubt, as time goes on, other factors may be shown also to be involved. At the present moment, then, we are attempting to define a field by a purely empirical method which, most students of the subject will agree, is unsatisfactory. Until we learn more about these agents, however, we must be content with the present state of affairs and, for the time being, define a filterable virus as a particulate agent, probably endowed with life, of a size and carrying an electrical charge which permits it to pass through the pores of ordinary filter candles, as a rule ultramicroscopic (though there are exceptions), related in many instances to the formation of intracellular inclusion bodies (cytoplasmic, intranuclear or both) and, since disease phenomena have focused our attention upon them, they appear to be capable of inducing pathologic processes in many forms of life, including man, lower animals, fowls, fishes, insects and plants. It is quite possible, of course, that filterable viruses exist which may not be at all pathogenic for any form of life. We may possibly have saprophytic filterable viruses as we do saprophytic bacteria.

It is readily apparent that the filterable virus field is in a somewhat chaotic state. There are so many questions

[1] For general reference to the literature concerning filterable viruses see "Filterable Viruses," by Rivers, 1928, and "Filterable Virus and Rickettsia Diseases," by McKinley, 1929.

which can not be answered definitely at the present time. There is the question of the living nature of viruses, for example. While we can not be sure that all viruses are living, in the same sense as we consider bacteria, yet the evidence seems to point in this direction. By the same token we can not properly evaluate and interpret at present the thesis of Beijerinck of a "contagium vivum fluidum," or that of Simon of a "contagium inanimatum" or our general concept of a particulate animate agent —indeed all are possible—but it seems probable that our definition will meet most of the demands of our present knowledge concerning these agents.

Having attempted to define the filterable viruses, let us look at the subject in retrospect. In 1874 Weigert studied the minute bodies in the lesions of smallpox which we now designate vaccinia bodies or Guarnieri bodies. These were later studied by Loeffler and Pfeiffer in 1886 and extensively by Guarnieri in 1892, after whom they have been named. In 1892 Iwanowski found that filtrates from mosaic diseased tobacco plants contained the infecting agent and that it remained active for several months. These observations formed the beginning of the filterable virus field. Since the beginning of the present century the major portion of discovery concerning this subject has taken place and at the present time there are no less than seventy diseases included in this group. Some of the historical landmarks of this discovery are as follows:

The demonstration in 1892 of the filterable nature of the virus of mosaic disease of tobacco by Iwanowski gave impetus to the development of the filterable virus field. The so-called pox bodies, which had been previously studied by Weigert and Loeffler and Pfeiffer, were thought to be protozoa up to this time. In 1892 Guarnieri described these bodies in some detail. In 1898 Frosch and Loeffler demonstrated the filterable nature of the virus of foot-and-mouth disease and a year later Beijerinck added to our knowledge of the tobacco mosaic virus and suggested the possible existence of a "contagium vivum fluidum." Events then followed rapidly. In 1903 Negri described the bodies which have been named after him in the central nervous system of animals dying of rabies. The presence of these bodies is characteristic of the disease. During the same year Borrel reported the presence of pox bodies in sheep-pox. In 1907 Ashburn and Craig demonstrated the filtrability of the virus of dengue fever and in the same year Prowazek demonstrated the so-called trachoma bodies in the epithelial cells of the conjunctiva from cases of this disease. Two years later, in 1909, Heymann, and also Linder, described inclusion bodies in a form of conjunctivitis found at birth and designated as conjunctivitis neonatorum. The previous year, 1908, Landsteiner and Popper succeeded in infecting monkeys with the virus of poliomyelitis and demonstrated that the virus is filterable. This work was confirmed the following year by Flexner and Lewis. In 1911–12 Peyton Rous demonstrated the filterable nature of an agent causing sarcoma in chickens, and these tumors have received much attention since that time in an effort to learn something regarding the etiology of human cancer and other new growths. The work of Gye and Barnard in 1925 gave a new stimulus to the study of these neoplasms as well as to other experimental tumors in animals. In 1913 Flexner and Noguchi reported the cultivation of the virus of poliomyelitis, though it now seems probable that these investigators did not actually succeed in cultivating the true virus of this disease. The same year Noguchi and Cohen described the cultivation of the minute bodies described by Prowazek in tra-

choma. It now seems probable that this work was erroneous in so far as the actual cultivation of the trachoma bodies is concerned, since Noguchi himself in 1927 described a Gram-negative bacillus, *Bacillus granulosis,* as the cause of this disease. Also, in 1913, da Rocha Lima claimed to have demonstrated the filtrability of the causative agent in verruga Peruviana, thought to represent a later phase of the disease described by Carrión and known as Oroya fever or Carrión's disease, but subsequent events seem to have established the etiology of this disease as a Gram-negative bacillus, the *Bartonella bacilliformis,* described by Noguchi in 1926–1927. It is worthy of special note, as the trend of events indicates, that Lipschütz at this time prepared a review of the filterable virus field. As early as 1913 this author was able to list some forty-one diseases affecting man and animals in which the filterable nature of the causative agent was then thought to be established with more or less certainty. It is true, however, that some of the diseases included in Lipschütz's review have since been shown to belong elsewhere. It is quite apparent as this subject developed that there was a tendency to place most diseases of unknown etiology in this group. It has been a very convenient waste-basket. Yellow fever is a notable example of this, for up until recent years there was no direct evidence that this disease is caused by a filterable agent and yet it was generally thought that when the true etiology of yellow fever became known it would be found to be a filterable virus. But in 1918 Noguchi described the *Leptospira icteroides* as the causative agent in yellow fever and for nearly ten years this work was quite generally accepted as proven fact. Sellards, in 1927, questioned the rôle of the *Leptospira icteroides* in yellow fever and demonstrated the identity of this organism with the *Leptospira icterohemorrhagiae* of Weil's disease. Then followed the work of the yellow fever commission in Africa which has established the filtrability of the causative agent of yellow fever.

We have made no mention of the bacteriophage which was first described by Twort in 1915 and later studied in great detail by d'Herelle. There is no question of the filtrability of the lytic principle but there is still controversy regarding the nature of this substance which d'Herelle believes to be a filterable virus. Further study will have to determine this question.

In 1918 the world was the seat of a great pandemic of influenza. The etiology of this disease had remained obscure in previous epidemics. Almost at the same time epidemics of encephalitis lethargica began to appear and many of these cases were preceded by attacks of influenza. Some investigators believed that encephalitis is related etiologically with the cause of influenza. In 1919 Strauss and Loewe claimed to have demonstrated and cultivated a filterable virus from cases of epidemic encephalitis, but their work has not been substantiated. In 1921 Levaditi, Harvier and Nicolau also described a filterable virus as the cause of the disease. Subsequent investigations of our own and others indicate, however, that the Levaditi virus is closely related, if not identical, with known strains of herpes virus. In 1920–22 Olitsky and Gates described a filterable organism, *Bacterium pneumosintes,* as the causative agent in epidemic influenza, but this work has not been adequately confirmed to establish it as the cause of the disease.

While some investigators have perhaps leaned too much toward the filterable virus field in their zeal to discover the causes of many of these diseases, there have, of course, been others just as insistent that known bacterial forms are

involved in many instances. For example, the influenza bacillus and the streptococci have had their insistent adherents in the case of epidemic influenza and both these organisms, the former only recently, have been discussed in connection with epidemic encephalitis. There has been so much debate, so much controversy, so many claims, without pertinent scientific evidence, that we must continue to think of these two diseases and, for that matter, many others which have been carelessly placed with the virus diseases as members of that group of diseases of unknown cause. More recently we have seen two other diseases connected with the filterable virus field, psittacosis and multiple sclerosis, but experience has taught us to wait conservatively for acceptable confirmatory reports.

No mention has been made thus far of another group of diseases, the so-called rickettsia diseases, in connection with the filterable viruses. It is doubtful whether this group has any relation to the filterable viruses, and yet there have been several observations which indicate that some of the rickettsia may possibly be filterable in some stage of their development. On the basis of these observations it seems that, for the present, we should at least make mention of this group of diseases in any discussion of the virus field. Sellards and Siler, for example, have described rickettsia bodies in dengue-fed mosquitoes. On the other hand is the original observation of Ashburn and Craig, subsequently confirmed, that the etiological agent in dengue fever is filterable. There are likewise the observations in connection with trench fever and tsutsugamushi disease, both of which have been etiologically assigned a filterable agent, and yet rickettsia have also been described for both. The question arises—are some of the rickettsia filterable, and if so, should such agents be included in the group of filterable viruses? This question can not be answered at the present time. For the present it seems best to consider the rickettsia in a group by themselves.

If one were to attempt to make a list of the diseases caused by filterable viruses and indicate by some symbol after the name of each whether the virus nature of the disease is definitely established or not it would be very difficult. This is due chiefly to the great differences of opinion which exist in the minds of investigators who have worked experimentally or at the bedside with these diseases. The writer is tempted to prepare such a list but realizes that it would be useless to do so, for probably no one would agree with him but himself. It is most certain, however, that a list of those diseases definitely proved beyond question to be caused by filterable agents would, at the present time, be very limited. However, in order to give some idea of the possible scope of the field, the reader is referred to the general literature dealing with this subject.

No discussion of the virus field would be complete without mention of the intracellular inclusion bodies which have been found associated with many diseases believed to be caused by filterable viruses. The presence of inclusion bodies has already been referred to in our definition. These inclusions are found in the cytoplasm of certain cells in some diseases and in other diseases they are found in the nucleus. In some diseases the inclusion bodies are found both in the cytoplasm of the cell and in the nucleus. On the basis of their location Lipschütz offered a classification in 1921. These peculiar bodies are found not only associated with some of the filterable virus diseases of man but are also found associated with certain diseases, thought or proven to be caused by filterable viruses, in other forms of life

such as lower animals, fowls, fishes, insects and plants. The exact nature of these bodies is unknown. However, it has been demonstrated recently by Woodruff and Goodpasture that the inclusion bodies of fowl-pox contain minute granules and fowls inoculated with the inclusion bodies have developed the disease. This would indicate, as has been suspected for some time, that the inclusion bodies may represent actual virus and their formation may be due to the reaction of the cell to the presence of the infecting agent in a protective mechanism designed to defend the cell from the invading virus. This theory is further supported by the recent production of inclusion bodies in cells in tissue culture by introducing virus material into the medium of these growing cells. On the basis of these observations it would seem logical to discount the theories that these bodies are the result of degenerative processes in tissue cells or that they are the result of leucocytic migration or fragmentation, as has been suggested by some investigators. Still we should not be too hurried in our decision regarding this matter, for, after all, only a selected few of the inclusions have so far been carefully studied and they may not all represent the same phenomena. Suffice it to say for the present that inclusion bodies are consistently found associated with certain of the virus diseases—so much so that they may, in most instances, be taken as evidence of virus infection. The exact nature of these bodies will have to be determined by future study. We have some hint as to what this may be, but further work will be necessary before many of the questions regarding the inclusion bodies and their relation to virus diseases can be answered.

When one considers the many important diseases affecting mankind and many other forms of life which have been thought of as possible virus infections, one is amazed at the possible extent of this field of investigation. Among the diseases affecting man, concerning which there is evidence of a filterable or ultramicroscopic causative agent, are smallpox, varicella, measles, epidemic parotitis, epidemic encephalitis, yellow fever, poliomyelitis, dengue fever, rabies, psittacosis, the common colds and epidemic influenza. Other important diseases such as cancer and multiple sclerosis have adherents who believe that their inciting agents are of virus nature. Among the diseases of lower animals we have the various forms of pox (cow-pox, sheep-pox, horse-pox, goat-pox, swine-pox), rabies, distemper, encephalitis in horses (Borna disease), Nairobi disease of sheep, African horse sickness, catarrhal fever of sheep, foot-and-mouth disease, hog cholera, rinderpest, pleuropneumonia, influenza and others, all of which are thought of at present as probable virus infections. Then there are fowl-pox and fowl diphtheria, fowl-plague, the sarcomata of fowls, leukaemia of fowls and others; there are the diseases of insects which include sacbrood disease of bees, the wilt diseases of the gipsy moth and the European nun-moth, jaundice of silkworms, etc.; there are the epithelioma of fish, carp-pox and lymphocystic disease of fish; and finally in the plant kingdom we have that large group of mosaic diseases which include mosaic of tobacco, sugar cane, tomato, potato, cucumber, lettuce, cabbage, mustard, turnip, spinach and many others. Among the rickettsia diseases of man we have typhus fever, trench fever, Rocky Mountain spotted fever and possibly others.

As a subject the filterable viruses offer tremendous opportunities for scientific study. A great deal of knowledge has accumulated during the past four decades, but as a field for investigation the filterable viruses seem only in

their infancy when one takes into account the many important and fundamental questions which need to be answered. We have given here only a brief glimpse of the terrain. Most of it is unexplored territory but it is a hopeful sign to see the extraordinary activity which has been focused on these problems during the past several years. One American university has, with vision and foresight, established a department for the study of this group of diseases. Another has added a course in the filterable viruses to its curriculum. No doubt further developments along these lines will occur as awakened interest and vision take the place of reticence. And the filterable viruses may offer a special field, just as the diseases of the various systems are specialized to-day in our modern medical institutions. The demands of progress and the needs for trained personnel may, of necessity, bring this about. Progress has been slow and no doubt will continue to be slow until some of the fundamentals are established. This has been true in the science of bacteriology (nearly two hundred years elapsed between the invention of the microscope and the discovery of the first disease-producing germ, the anthrax bacillus). The cultivation of the first bacterium on artificial medium gave to the science of bacteriology a fundamental working tool. Looking ahead in the field of the filterable viruses our greatest need is for working tools, new ideas and methods of approach. As these become available fundamental progress will be made and many of the mysteries now surrounding the filterable and ultramicroscopic agents will be solved. The diseases caused by these viruses will then be conquered by preventive and curative means.

HYDRAULIC RESEARCH AT THE BUREAU OF STANDARDS[1]

By H. N. EATON

BUREAU OF STANDARDS, WASHINGTON, D. C.

THE last session of Congress marked the successful termination of the long-continued effort to have established at the U. S. Bureau of Standards a national hydraulic laboratory adequately equipped to permit of fundamental research in all branches of hydraulics, for the purpose of furthering our knowledge of the complicated processes of water-flow, for determining more accurately the numerical values of experimental constants involved in the formulas used in the design of hydraulic structures, and for making laboratory tests on small models of proposed dams, spillways, canal locks, river control works and similar structures.

Such studies are not merely of academic interest, but the results are capable of immediate application to the design of the immense hydraulic projects costing hundreds of millions of dollars which are now being undertaken by our federal government, by the states, by municipalities and by private interests. We have already embarked upon the extension of our inland and coastal waterways, at a probable cost in excess of $500,000,000. Flood control of the Mississippi and other rivers will cost us many hundreds of millions of dollars during the next decade. The immense Boulder Dam on the Colorado River is to

[1] Publication approved by the Director of the Bureau of Standards of the U. S. Department of Commerce.

be constructed at a cost of $165,000,000. Consideration is being given to the construction of the Nicaraguan Canal at a cost undoubtedly in excess of $500,000,000. Immense sums are being expended every year on irrigation projects, on hydroelectric plants and on water-supply projects.

Obviously any means which will permit a saving of even a small percentage of the cost of these huge projects will mean the saving of millions of dollars. This can be done with the aid of the hydraulic laboratory. The investigations conducted in its experimental flumes furnish more exact information to the designers of hydraulic structures and enable them to effect economy through the more accurate knowledge of the processes of flow with which they have to deal. Tests on models of proposed structures point out the most effective design, give added assurance that the structures will function as planned and indicate how maintenance costs can be reduced.

Of late years hydraulic engineers in this country have become more and more aware of these facts and are now sending their problems in rapidly increasing numbers to the few suitably equipped hydraulic laboratories in our engineering colleges. At present the laboratories at the Worcester Polytechnic Institute and at the State University of Iowa are actively engaged to their full capacity with model tests of hydroelectric power projects and other problems relating to the flow of water over spillways and in open channels. The laboratories at the Carnegie Institute of Technology and the Massachusetts Institute of Technology also are rapidly becoming more active in this respect, and other college laboratories are undertaking this type of investigation.

Nevertheless, in spite of the growing utilization of the hydraulic laboratories in the engineering colleges, many hydraulic engineers have felt that there was great need for the establishment of a national hydraulic laboratory to be operated by the central government, as is done in a number of European countries.

John R. Freeman, the internationally known hydraulic engineer, was first to propose publicly a national hydraulic laboratory, but Senator Joseph E. Ransdell, of Louisiana, had also conceived the same idea at an early date. As a result of conferences with Mr. Freeman, Senator Ransdell, in the Sixty-seventh Congress, 1921, introduced a resolution for the purpose of establishing such a laboratory. This failed to pass and it was not until May, 1930, that the bill to establish such a laboratory at the National Bureau of Standards finally passed the Seventy-first Congress, largely through the legislative efforts of Senator Ransdell and his colleague, Congressman James O'Connor, of Louisiana. The bill received the support of nearly the entire engineering profession. Dozens of prominent engineers testified in its favor at the hearings or wrote letters urging the passage of the bill. About forty engineering societies and associations also supported it. In particular, John R. Freeman gave lavishly of his time and money to focus public attention upon the matter and used his influence wherever possible to bring about the passage of the bill. Rarely has there been such wide-spread interest in any piece of legislation of this nature.

The bill was also supported by several government departments which deal to a large extent with hydraulic problems, in particular, the Bureau of Reclamation and the Geological Survey of the Department of the Interior, and the Bureau of Public Roads of the Department of Agriculture. Each of these departments has hydraulic problems which are in urgent need of solution and which can be investigated in the new laboratory. In spite of its immense construction projects in connection with

irrigation works, the Bureau of Reclamation has never had a hydraulic laboratory in which it could study the problems arising in the design of its structures. Its capable staff of engineers has solved the problems confronting it as well as any other body of engineers in the world could have done without the aid of a laboratory, but we have their own testimony that the National Hydraulic Laboratory will be a valuable aid to them in their work. For example, in the design of the Boulder, Dam, which will be the highest dam in the world, there are problems for which the engineers can find no precedent, and which will therefore require experimental study. A single mistake in the design of such a structure, because of lack of exact information as to how the water will flow, might easily cost more than the National Hydraulic Laboratory.

The Bureau of Public Roads is interested in obtaining more accurate information as to the flow of water in irrigation ditches and its measurement, the backwater caused by bridge piers and other obstructions in streams, the scour about piers, etc. The Geological Survey is interested mainly in the measurement of stream flow. Its principal need is more exact information as to the various types of measuring devices, such as weirs and dam sections of various kinds, current-meters, etc. It needs, in particular, tests of current-meters in flowing water, in order that moving water calibrations may be compared with still water calibrations to determine the effect of turbulence on their indications.

The new laboratory will have three principal functions. First of all, it will be a place where fundamental research can be conducted with the advantages of continuity of effort and staff and with ample equipment. It will add to our general knowledge of water-flow phenomena by determining accurately flow coefficients, friction losses in various structures, the laws of the movement of gravel and silt in rivers and canals, erosion below spillways and similar problems.

In the second place, its staff will make model studies of proposed hydraulic structures to determine the form which is most effective in producing the desired results and which will be the cheapest to build and maintain.

The third function of the laboratory will be to conduct routine tests on all kinds of hydraulic instruments, meters and accessories, such as water-meters, current-meters and Venturi meters.

The laboratory will probably be engaged principally with special studies and general investigations for the government departments, states and other political subdivisions, which now have no adequate hydraulic laboratory facilities. It will not enter into competition with college and commercial hydraulic laboratories but will rather aim to encourage such laboratories in any way possible. This is in accord with the general policy of the National Bureau of Standards not to undertake tests or studies which can be adequately and conveniently conducted elsewhere.

The laboratory investigations which are required by hydroelectric companies and manufacturers of hydraulic machinery and which are being undertaken in increasing numbers every year should be, and undoubtedly will continue to be, conducted in the laboratories of the engineering colleges or by the individual companies themselves. This does not mean, however, that private individuals or organizations will be precluded from bringing to the National Hydraulic Laboratory problems which other laboratories are not equipped to handle.

The laboratory is to cost approximately $350,000, including built-in equipment such as pumps, supply tanks, concrete flumes, a standpipe, etc. The plans are now being considered by an advisory committee selected from the

most prominent hydraulic engineers in the government departments and in civil life. It is impossible to predict at this early date what the exact form of the building and the nature of the equipment will be. However, in all probability there will be a very large concrete flume in which several hundred cubic feet of water per second can be circulated, a series of smaller glass-walled flumes of various widths from 1 foot up to 4 feet, a long shallow steel flume which can be tilted a few degrees from the horizontal, a cylindrical standpipe to furnish high heads, large basins for volumetric measurement and weighing tanks for measuring very accurately flows up to about 10 cubic feet per second. There will also be provided a large floor space free from fixed equipment and supporting columns for the construction of models of dams, rivers and such structures as will require study from time to time.

The water used in the tests will be circulated by means of pumps; that is, there will be large, low-lying concrete supply basins filled with water which will then be pumped to higher steel tanks arranged with overflow weirs to maintain constant head. From these tanks the water will flow by gravity to the model being tested, will then pass to weighing or measuring tanks and then be returned to the supply basin.

The flumes with plate glass sides will furnish a clear view into the flowing water so that complicated flow phenomena can be studied visually and photographically. Photography plays an important rôle in the modern hydraulic laboratory, since in this way transient phenomena which are often too rapid for the eye to grasp can be recorded permanently. Of late the moving picture camera has come into general use for this purpose, particularly because the projector can be used to slow down the phenomena until rapid fluctuations can be followed with the eye and understood.

Every one is familiar with the astounding advances which have been made possible in aeronautics during the past quarter of a century through research in the wind tunnel, that is, in the aerodynamic laboratory. We are just entering upon a similar era of progress in hydraulic engineering in which research in the hydraulic laboratory will lead us to a more intimate knowledge of the laws of flowing water and the most effective ways of applying them for the benefit of mankind.

THE SCIENCE OF PHOTOGRAPHY[1]

By Dr. C. E. KENNETH MEES

EASTMAN KODAK COMPANY, ROCHESTER, N. Y.

UNTIL quite recently, the scientific world has shown little interest in the science of photography as distinguished from its practice. Even the references to photographic theory in general textbooks are brief and frequently misleading. The introduction of sound into motion pictures, however, has brought the subject to the attention of a new section of the scientific public. That introduction was brought about by physicists and engineers trained primarily in the science of electricity, and when they started to apply the methods of sound recording to motion pictures, they were, of course, faced with photographic problems the pursuit of which brought them into contact rather closely with the development of photographic science.

The science of photography deals with the physics and chemistry of light-sensitive substances and especially of the silver compounds used in the art of photography. It touches at many points the fundamental sciences from which it is derived. Its physics is a branch of physical optics, and in chemistry it comes in contact principally with physical, colloid and organic chemistry. The apparatus and methods used in photographic research have, however, become very specialized; its experimental methods are in many respects quite different from those employed in other fields of scientific work.

The subject falls naturally into two

[1] Being the ninth annual Sigma Xi address, delivered December 30, 1930, on the occasion of the meeting of the American Association for the Advancement of Science, Cleveland, Ohio.

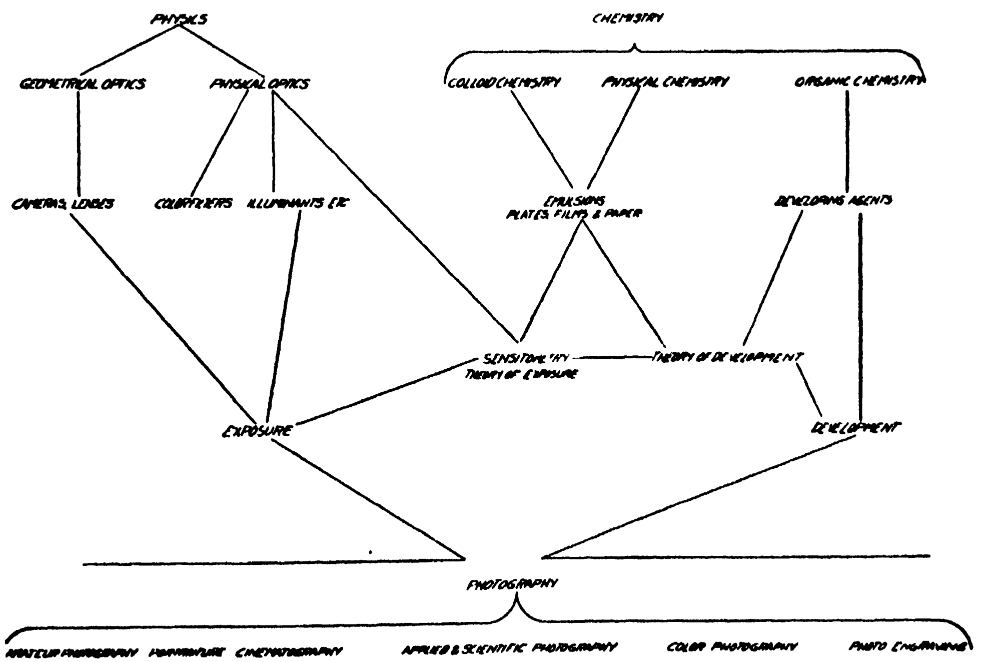


FIG. 1. DIAGRAM OF RELATION OF SCIENCES.

divisions: (1) the study of the light-sensitive substance itself and the changes which it undergoes in its transformation into an image; (2) the properties of that image when obtained and their relation to the original distribution of light and shade by which the image was produced.

1. The light-sensitive substance which is used in modern photography, and which is known as the "emulsion," is produced by precipitating silver bromide —usually containing some silver iodide —in the presence of gelatin, washing out all the water soluble substances present, and drying it down into a thin film coated on a support, which may be glass, cellulose base film, or paper. The light-sensitive layer thus consists of a sheet of gelatin which, in the case of materials used for making negatives, is about 40 microns thick, and in which are imbedded grains of silver bromide of an approximately triangular or hexagonal shape, varying in size from less than 1/2 to 4 to 5 millimicrons in diameter. When these crystals are affected by light, they undergo a change, as a result of which, when placed in a photographic developer, which is an alkaline solution of a weak reducing agent, the silver bromide of the grain is transformed into micro-crystalline metallic silver.

The study of these phenomena can be divided into four different sections:

A. The nature of the change which the silver halide crystals undergo when they are affected by light.

B. The nature of the product of that change; that is, the material produced which enables development to be effected.

C. The physical chemistry of the development process itself.

D. The relation of the size and sensitiveness of the different crystals to the effect produced after development; that is, to the curve showing the relation between the exposure and the mass of silver produced.

These four sections, dealing with the phenomena of exposure and development, comprise that part of the science of photography which deals with the nature of the photographic process itself.

2. Further, the science of photography deals with the nature of the final image produced and its relation to the optical image from which it was formed. This also may be divided into sections:

E. The relation between the brightness of the various areas of the image and that of the corresponding areas of the original, which is known as "the theory of tone reproduction."

F. The structure of the image itself. The sharpness which is obtained in a photographic image is of importance primarily in connection with the resolving power of the photographic material. Photographic images show a certain amount of graininess, and in connection with their use as measuring instruments small distortions occur, the nature and extent of which have been studied.

G. The spectral sensitivity of the materials, both natural and after treatment with optical sensitizing dyes, occupies an important place in the science of photography.

H. Finally, in order to apply photographic materials in photometry, we need a knowledge of the theory of tone reproduction, the characteristic curve, the developing properties of the material, and the spectral sensitivity; in fact, we must be in a position to apply our whole knowledge of the science of photography to the subject.

In the early history of photography, investigators were occupied chiefly in attempting to improve the processes themselves with a view to obtaining photographic results of better quality or taking photographs with a shorter time of exposure. Whatever strictly scientific investigation there was was concerned with theories of the action of light and the part played by it in the production of the image. Quantitative measurements of the photographic process were

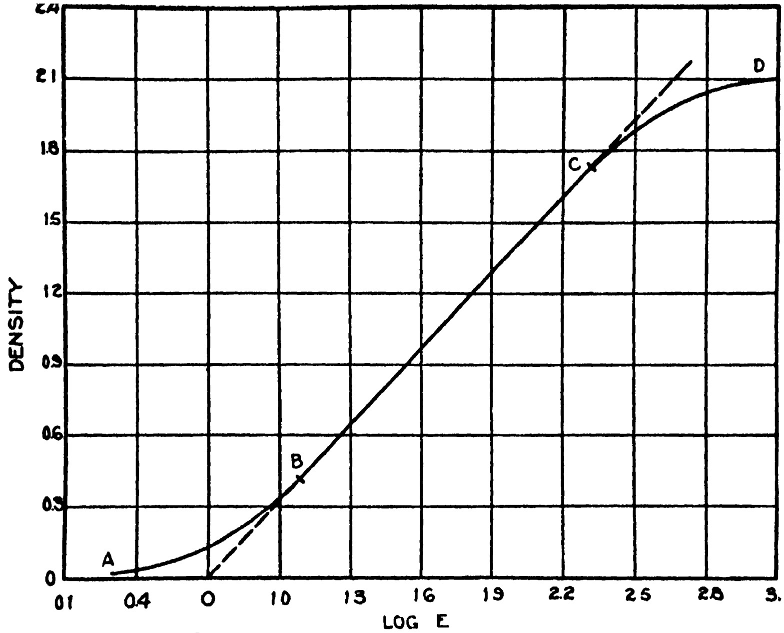


FIG. 2. CHARACTERISTIC CURVE.

not made until more than thirty years after photography had been established as a medium for the reproduction of images, and modern photographic science dates primarily from the publication in 1820 by Ferdinand Hurter and V. C. Driffield of a paper entitled "Photochemical Investigations," in which they studied systematically the relation between exposure and development and the deposit of silver produced in the photographic process.

They first defined the photographic density, *D*, as being the logarithm of the *opacity*, which was defined as the inverse of the transparency. Thus, if we have a light of intensity *I* incident upon a photographic deposit, and *I′* is transmitted,

$$T \text{ (the transparency)} = I'/I,$$
$$O \text{ (the opacity)} = I/I' = i/T,$$
and
$$D = \text{density} = \text{logarithm of } I/I' \text{ or } -\log I'/I.$$

Hurter and Driffield showed experimentally that the density *D* of a given silver deposit is proportional to the mass of silver per unit area contained in the deposit. This result was confirmed by other workers, but it has recently been shown that the relation is only approximate and that there is a considerable departure from true proportionality with variations of exposure and development. A deposit transmitting approximately one tenth of the incident light, that is, having a density of 1, contains about 1/10 mg of silver per square centimeter of the film.

Basing their studies on their definition of density, Hurter and Driffield exposed photographic plates for definite times to a standard candle by means of a rotating wheel having cut-out sectors. The plates were developed, fixed, washed, dried, and the densities plotted on a chart with the logarithm of the exposure as abscissae and the densities as ordinates, as is shown in Fig. 2. This shows what is known as the *characteristic* curve of an emulsion. There are three fairly well-defined regions of the curve. Thus, from *A* to *B*, we have the initial part, convex to the *log E* axis, which may be termed the "region of under-exposure"; between *B* and *C*, known as the "region

of correct exposure" (the increase of density is practically constant for each increase of exposure, being arithmetical for each geometric increase of exposure); and in the third region, from *C* to *D*, this arithmetical increase fails, until the density becomes constant; this is the "region of over-exposure." By prolongation of the straight-line portion of the curve, the *log E* axis is cut at a point which Hurter and Driffield termed the "inertia," which, when divided into a factor, gives the "speed" of the plate.

Hurter and Driffield studied the effect of the duration of development upon this characteristic curve and found that within certain limits the curve rotates around the inertia point, the effect of development being measured as an increase in the slope of the straight line portion, which they termed the "development factor," and to which they assigned the Greek letter γ. The increase of γ with time of development is exponential, a limit being reached with prolonged development, which is generally known as gamma infinity ($\gamma\infty$). Photographic materials therefore may be classified by the values which they give for the *inertia,* a measure of the insensitiveness of the material, and of $\gamma\infty$, which is a measure of the limiting contrast which can be obtained, while the reproduction of tone values may be expressed as the *shape* of Hurter and Driffield's characteristic curve. Hurter and Driffield thus established photographic science on a firm quantitative basis, which the work of many other investigators has expanded and modified in details without affecting the foundation which they laid down.

Like all photographic investigators, Hurter and Driffield were interested in the reaction which silver halide undergoes when exposed to light and in the nature of the product of that reaction, on which development is based. They thought that information as to this could be obtained from the work which they had done in measuring the quantitative relations of the image, but in the course of time it has become clear that the nature of the action of light upon the photographic material and of the product of that action must be sought by a study of the individual grains rather than by the measurement of the total density.

The study of the action of light on the individual crystal grains was commenced by Svedberg in Upsala in 1920. Svedberg spread out the emulsion in a very thin layer so that he could count the number of grains occurring in a unit area and classified these according to their size. Another portion of the layer was then exposed and developed and the silver removed by means of a silver solvent, and the grains of silver bromide which had not been developed and removed were then counted. In this way Svedberg established the fact that the likelihood of a grain becoming exposed followed the laws of probability, and that the larger grains were more likely to become exposed than the smaller grains. This work was followed up in England by the staff of the British Photographic Research Association and in our laboratory by S. E. Sheppard, A. P. H. Trivelli, E. P. Wightman, and others, and the sensitiveness relations of the individual grains of photographic emulsions were soon worked out. As an explanation of the facts found, Svedberg suggested that the sensitivity is concentrated in certain specks on the surface of the grains, and Clark and Toy of the British Research Association considered that these specks must be composed of some material alien to silver bromide. The nature of the specks has been elucidated as a result of the work by Sheppard on gelatin. Sheppard and Punnett had found that in gelatin there is present some material which, when added to an emulsion during manufacture, would enhance the sensitivity, and this material was found to be dissolved out during the

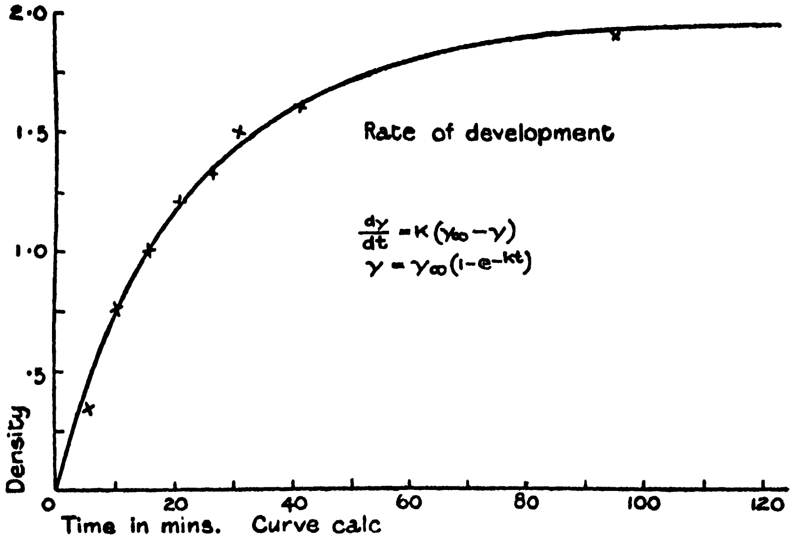


FIG. 3. INCREASE OF γ WITH TIME OF DEVELOPMENT.

acid wash which follows the liming of the raw materials used in the manufacture of photographic gelatin. Sheppard concentrated the material from the acid wash liquors and after a great deal of work identified it as allyl mustard oil. He showed that this, after being transformed into allyl thiocarbamide, reacts with silver bromide and forms a crystalline addition product which breaks down to give silver sulfide. The special sensitiveness of the silver bromide crystals occurring in high speed emulsions can therefore be ascribed to the presence on their surface of ultra-microscopic specks of silver sulfide. This suggestion, advanced in 1925, has met successfully the criticism directed against it and the theory is now generally accepted.

Throughout the history of photography there has been much controversy as to the nature of the material produced from light-sensitive materials by exposure to light which permits their subsequent development. The exposed material is generally said to contain a "latent image," and there has been much speculation as to the nature of this latent image. Some thirty years ago there were two rival theories on this subject, one school holding that the latent image consisted of a sub-halide of silver and the other that it consisted of metallic silver. There were various other suggestions, such as that the latent image represented merely a physical strain of some kind in the silver halide and not a definite chemical compound. At the present time, however, almost all photographic workers are agreed that the latent image is composed of metallic silver, which in development acts as a nucleus for the deposition of further silver produced by the reduction of the silver halide by the developer. A theory of the mechanism of exposure therefore has to account for the reduction of silver halide or silver sulfide or both to metallic silver at the points on a silver halide crystal where specks of silver sulfide occur. A number of hypotheses have been offered to elucidate this mechanism, among which should be mentioned the concentration speck theory of Sheppard, Trivelli and Wightman, according to which the energy falling on the whole crystal is concentrated at a boundary between the silver sulfide specks and the silver bromide and there effects liberation of metallic silver by the release of bromine atoms.

Recently Toy and Trivelli have called attention to the importance of the photoconductivity effect; that is, the increase of the conductivity of silver halide when exposed to light, which, linked with the production of photopotential under the influence of light, may possibly develop a complete mechanism for the exposure of the photographic material.

The photoelectric phenomena associated with exposure are also being studied by the use of layers of silver halide on silver plates free from gelatin. These when exposed to light produce a potential first in one direction and then in the opposite, the explanation offered being that the first potential corresponds to the release of electrons from the silver bromide which reach the silver plate and charge it negatively, these being followed by the slower moving bromine atoms which are positively charged.

Turning from exposure to development, the idea that the latent image acts as a nucleus for development has for many years been accepted as the basis for theories of photographic development, and the development reaction itself can be dealt with as a problem in chemical dynamics, it being treated as a heterogeneous reaction involving the solution, reduction and deposition of the solid silver bromide by the developer.

The chemical reactions which the developer itself undergoes are very complicated in the case of the organic developers. A very simple development reaction is that which occurs with the ferrous oxalate developer, and this may perhaps be taken as the prototype for photographic development. Ferrous oxalate, which is insoluble in water, dissolves in potassium oxalate to form a red solution of potassium ferro-oxalate. This reacts with silver bromide, reducing it to metallic silver, and produces potassium ferri-oxalate and potassium bromide. The reaction can be represented by the following equation:

$$K_2Fe(C_2O_4)_2 + K_2C_2O_4 + AgBr \rightleftarrows K_3Fe(C_2O_4)_3 + KBr + Ag.$$

If the developed image is treated with a solution of potassium ferri-oxalate and potassium bromide, the silver bromide is reformed and this is therefore a simple reversible reaction.

When we deal with organic reducing compounds, the development reaction is very much complicated because these compounds will not reduce silver bromide when alone in solution, and their oxidation products react with the other necessary components of the solution. Thus, in one of the simplest cases, the oxidation product of hydroquinone, quinone, will react even with alkali, which must be present in order to permit hydroquinone to develop at all, while in the usual developer, containing both alkali and sulfite, the reactions are very complicated, the hydroquinone being eventually removed from activity by its transformation into hydroquinone sulfonates. In the case of the other developing agents—pyrogallol, paraminophenol, and its substituted derivatives—the chemistry of the reaction and the end products are not known at all.

The velocity of development is usually followed in photographic work as an increase of the H and D development factor γ; that is, the slope of the straight line portion of the characteristic curve. This increases rapidly at first and then more slowly until it reaches a limit, which is known as "$\gamma\infty$" corresponding of course to a limit of density which can be developed for a single exposure, $D\infty$. The relation between γ and time of development is an exponential one and can be represented approximately by the usual equation of the first order, so that the progress of development can be stated in terms of two factors:

$$\gamma_t = \gamma\infty\ (1 - e^{-kt}),$$

$\gamma\infty$ the limit to which development can be carried, and K, the velocity constant of

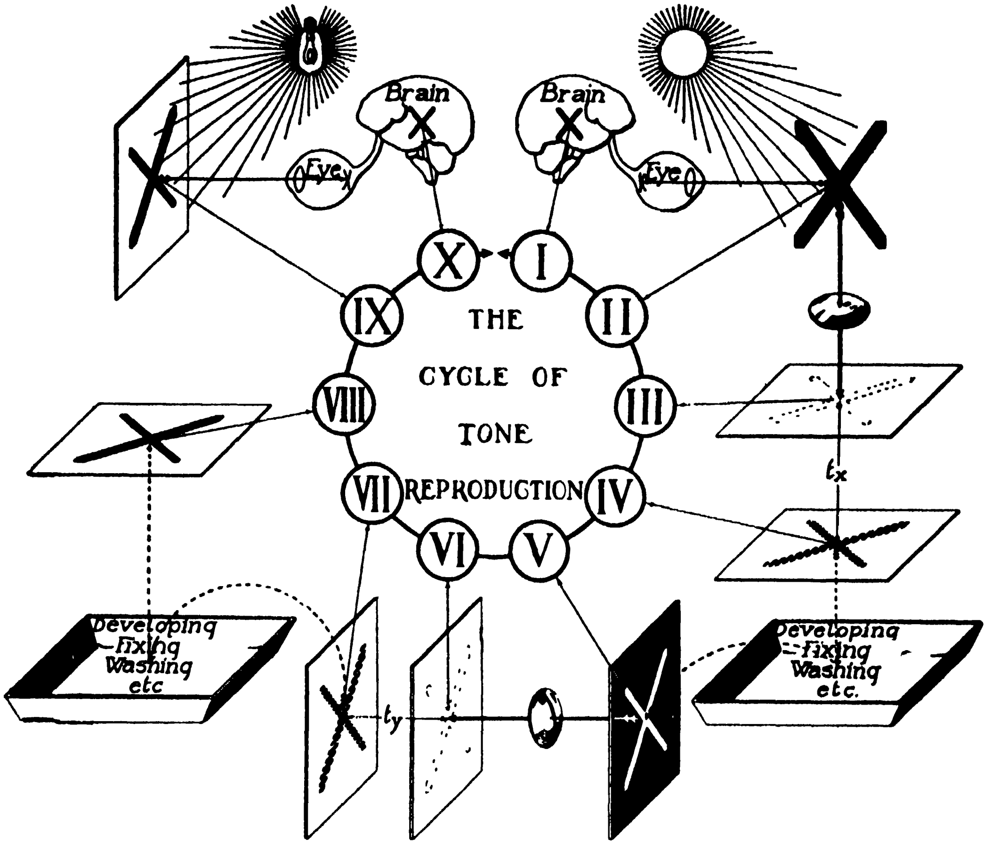


FIG. 4. CYCLE OF TONE REPRODUCTION.

development. Thus with the practical developers used, this simple equation does not hold perfectly and various closer approximations are employed to represent the facts with the organic developing agents.

Turning to the study of the final image produced as a representation of natural objects, when a photograph of a natural object is made, the form can be represented only by differences in brightness. The accuracy with which the form is represented depends upon the precision with which the tones of the original subject are reproduced, and this subject, generally known as "the theory of tone reproduction," is fundamental to every photographic application. Psychologically, it is the apparent brightness which is of importance, but this can conveniently be treated as the physical brightness modified and interpreted by the eye and brain, and since it can be shown that throughout a wide range the apparent brightness is proportional to the physical brightness, it is usually sufficient in photography for tone reproduction to deal with the physical tones in the original and the reproduction.

The cycle involved in tone reproduction is illustrated in Fig. 4. In the right top corner, the object, in the form of a cross, is supposed to be illuminated by sunlight and is viewed by an eye the image in which is conveyed to the brain and there produces a subjective impression corresponding to the objective image on the retina. An image of the object is projected by means of

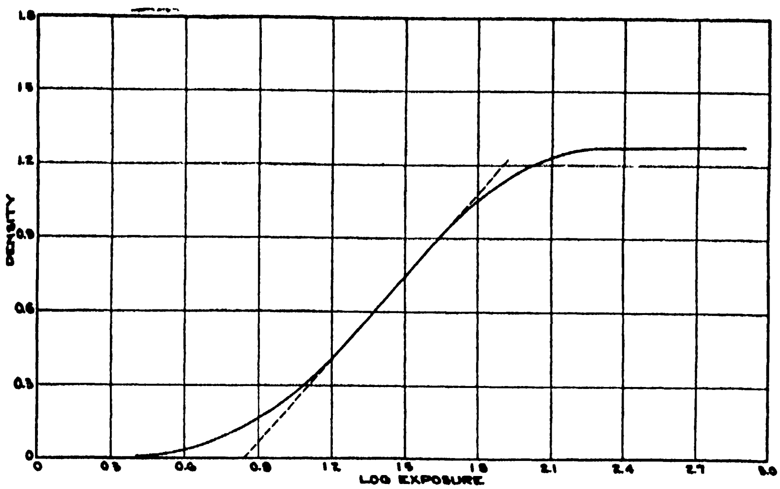


FIG. 5. CHARACTERISTIC CURVE OF A PHOTOGRAPHIC PRINTING PAPER.

a lens on to the sensitive material which, after chemical treatment, gives a silver image (a negative), corresponding to the various degrees of brightness in the original object. This negative is then printed upon the positive material, which, after similar treatment, gives a positive which is viewed usually at a brightness level different from that by which the original object was viewed and produces again a subjective impression. The whole cycle of tone reproduction is expressed by the relation of the subjective impression produced by the positive print to the subjective impression produced by the original object, but in practice it is sufficient to compare the objective print with the objective original.

The brightness differences which occur in nature may be due to differences in either the reflecting power of the various portions of the subject or the illumination. Since in natural scenes both the reflecting power and the illumination vary—some parts of a landscape consisting of clouds in sunlight and others of dark rocks in the shade—the range of contrast is often very considerable. For photographic purposes a scale or contrast of 1 to 4, in which the brightest thing is only four times as bright as the darkest, is very low, and such a subject would be called flat; a contrast of 1 to 10 is a medium soft contrast; 1 to 20, a strong contrast; 1 to 40, very strong; and 1 to 100 an extreme degree of contrast. All these degrees of contrast, for instance, occur in landscapes, street, and seashore scenes. (See pages 418, 419, 420.)

When an image of a natural object is produced in a camera, the relative brightnesses of the various tones will not be the same as those which were observed by the eye because the light in traveling from the object to the sensitive material in the camera will have suffered a certain degree of scattering which will affect the distribution of brightness among the various tones of the image. There may be some scattering in the air, and there will certainly be a good deal of diffuse light produced by the lens system. This will tend to lower the contrast in the image as compared with that of the original.

In the making of the negative, the reproduction of tone will depend upon the characteristic curve of the photographic material, as shown in Fig. 2. If the exposure is so arranged that all the tones of the original subject fall on the straight line portion of this curve,

the inverse reproduction in the negative will be proportional, and if, in addition to this, development is so arranged that the negative has a γ, that is, slope of the straight line, of unity, then the reproduction will be correct. In the print also, it is necessary that γ should be unity, or, if the γ of the printing material is not unity, it is necessary that the γ of the negative should be modified suitably, so that $\gamma_{neg.} \times \gamma_{pos.} = I$.

The last step in the making of a photograph is the printing of the negative, and where the print is to be viewed by reflected light it is this step which introduces the largest amount of distortion in the reproduction of the tones. As is seen in Fig. 6 the straight line portion of a paper curve is usually short, and it is necessary in printing, moreover, to utilize at least the under-exposure portion of the paper curve. In making a paper print, therefore, the tone values are always distorted to some extent, especially those in the highlights corresponding to the under-exposure portion of the paper curve, only the portion of the picture falling on the straight line portion of the characteristic curve of the paper being correctly rendered.

The computation of the tone reproduction in any photographic operation is of great importance, especially in the applications of photography, such as processes of color photography or the reproduction of sound. This computation can be performed by means of graphic diagrams incorporating the characteristic curves of the negative and positive materials, and it is possible therefore to follow the whole process of the reproduction of tone in photography from the brightnesses of the original object to the distribution of light and shade in the finished print.

In scientific work the physical nature of the developed photographic image is often of considerable importance. As has been explained, the image is granular in structure, and its sharpness depends upon the structure both of the developed image and also of the sensitive emulsion. The sharpness of the image may be expressed as the "density gradient at the edge." Suppose that a sharp knife edge be placed upon the emulsion and a collimated beam of light be allowed to fall normally upon the emulsion surface. Then after development the density at various distances from the edge may be measured with a microphotometer. If the density be then plotted as a function of the distance into the geometric shadow of the edge, the resultant curve may be termed the "sharpness curve," the sharpness being the angle of the straight line portion of this curve. Two functions of the emulsion influence the form of this curve: one is the spreading of light into the emulsion, which depends upon the reflection and refraction by the crystals of silver halide and on their absorption of the light; the amount of this spreading can be computed. This effect is known as the "turbidity" of the emulsion, and it is measured by the increase in the width of an image of a slit. The increase of the width of such a slit is proportional to the logarithm of the exposure, and the constant of proportionality, termed by Ross the "astro-gamma," is a measure of the turbidity. The other factor in sharpness is the development factor; that is, the slope of the characteristic curve, but the development factor at the edge of an image is not identical with that for a large area owing to the great variation in the development reaction in such a case over very short distances. Since the turbidity and absorption of an emulsion vary with the wave-length, the sharpness curve also varies with the wave-length.

Since the developed photographic image has a grain structure, it follows that under magnification any image must ap-

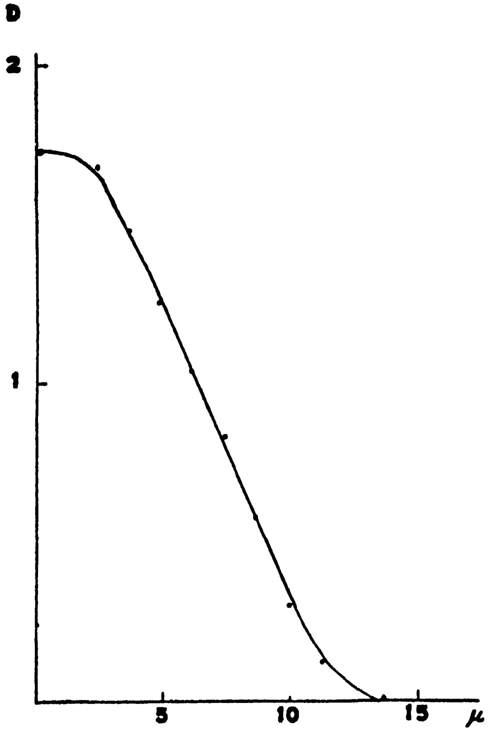


FIG. 6. SHARPNESS CURVE.

pear broken up to an extent depending on the size and arrangement of the grains. There are three phases in the inhomogeneity of a photographic deposit: (1) graininess due to the existence of the individual particles of silver; (2) graininess due to clumping of these particles and (3) graininess due to the agglomeration of the clumps. It should be understood that these phases are not separated by any distinct line of demarcation but merge by imperceptible gradations into each other. The impression of graininess is the result not only of the size of the grains of which the deposit is composed but also of their distribution and arrangement in groupings of various kinds.

The graininess may be measured and specified numerically, the method used depending upon the assumption that the graininess of a deposit is directly proportional to the distance at which the appearance of graininess becomes just imperceptible, provided that all other factors upon which depends the ability of the eye to distinguish homogeneity are constant. In order to avoid errors due to differences in the criterion, the distance at which the graininess to be measured disappears is compared with the distance at which structures of known periods disappear. Cross-line screens are chosen as the fixed structures with which the graininess is to be compared, so that a given graininess may be expressed by saying that it is equivalent to a screen of 3,000 lines to an inch, it being implied by this that a 3,000 line to the inch screen and the graininess in question would both just become visible at the same magnification.

The resolving power of a photographic material is a complex matter dependent on the sharpness and on the graininess, and as would be expected, the resolving power is not a fixed constant for a photographic material but is dependent both on exposure and on development, a range of resolving powers from 40 to 80 being sometimes obtainable by modification of development and exposure, which affect all three factors: the penetration of the light, the development factor, and the graininess, which enter into the determination of resolving power.

The resolving power is best determined practically by photographing narrow lines close together and observing the closeness of the lines which can just be resolved. Laboratory tests of photographic resolving power, however, can not be applied directly without correction to physical measurements. In laboratory tests the contrast between light and shade in the detail is very high and the optical system is arranged to enable this high contrast to be obtained. In astronomical work the contrasts in fine detail are not nearly so great, and very often the resolving power of the optical system, including the atmosphere, is of the same order as that of

the photographic material. Under these conditions the resolving power of the material is greatly diminished because of the low contrast of the object photographed. In spectroscopy the theoretical resolving powers are more likely to be applicable for bright line emission spectra, but in absorption spectra and to some extent in emission spectra the resolving power must be measured for the experimental conditions obtaining. The resolving power is of course dependent on the wave-length.

The light-sensitive compounds of silver are sensitive primarily to radiation of wave-lengths less than 500 mμ, and their sensitiveness to the longer wave-lengths of the spectrum is exceedingly slight. As early as 1873, however, it was discovered by Vogel that sensitivity to longer wave-lengths could be conferred by the treatment of the emulsion with certain dyes. Since that time the use of dyes for sensitizing photographic materials has extended very greatly, so that a large proportion of all photographs are taken upon materials which are sensitive in some degree to the whole of the visible spectrum, the use of "panchromatic" film, as it is termed, being almost universal in the motion-picture industry.

Until recently, the so-called "orthochromatic" materials were sensitized only for the yellow-green region of the spectrum, in addition to their normal sensitiveness for the shorter wave-lengths, obtained by the addition of erythrosine to the emulsion. The introduction of the polymethine dyes has made it possible without difficulty to prepare materials sensitive to the whole of the visible spectrum, their sensitiveness to red and green being *only slightly* inferior to the sensitiveness to the blue-violet. Since the eye is very insensitive to the blue-violet in comparison with its sensitivity for the green and orange, in order to get orthochromatic reproduction it is necessary to use a yellow filter to diminish the amount of the blue light forming the image, and in this way colored objects may be reproduced so that the relative intensities are directly comparable with those seen by the eye.

The very high sensitiveness now available throughout the spectrum eliminates any difficulty in making photographs by selected light corresponding to any spectral region, and a large number of light filters are employed for this purpose in photographic work. In color photography and in special work, such as photography from the air, it is quite feasible to take exposures of very short duration by means of red or green light, and the photography of spectra, even of stellar spectra, throughout the visible spectrum presents no difficulties.

There are a few dyes whose absorption

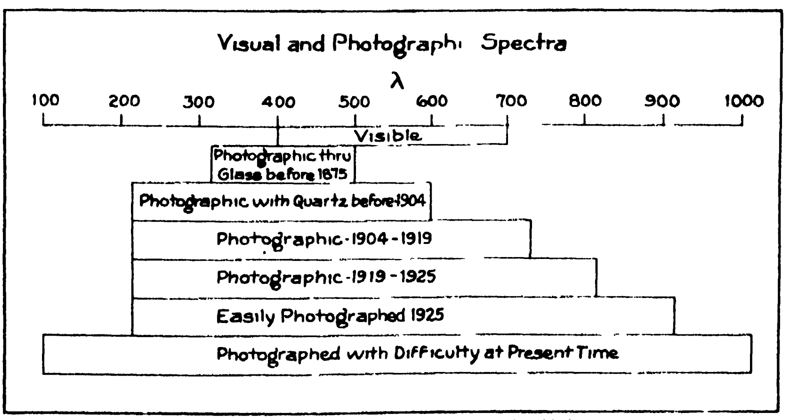


FIG. 7. EXTENSION OF SPECTRUM

LANDSCAPE PHOTOGRAPHED BY BLUE LIGHT.

bands and sensitizing power lie in the extreme red or even in the infra-red beyond the visible spectrum. Kryptocyanine, a dye discovered by Adams and Haller, in 1919, enables photography to be done without difficulty in the spectral region between 700 and 800 mμ, and very interesting photographs have been made by its use. In landscapes photographed by light of this wave-length, for instance, the blue sky appears almost black, since very little radiation of this wave-length is scattered by the sky, and the high reflecting power of chlorophyll in this region makes foliage appear white. These phenomena were pointed out by R. W. Wood more than twenty-five years ago W. H. Wright and others have used kryptocyanine in their studies of the surface of the planets, and A. W. Stevens, while on an expedition for the National Geographic Society, has succeeded in making aerial photographs with an exposure as short as 1/50 of a second from very high levels; he obtained a satisfactory photograph of the peaks of the Andes range at a distance of over 300 miles, the penetration of the atmosphere by light being proportional to the fourth power of the wave-length and therefore very great for the extreme red.

For the infra-red beyond 800 mμ, which is of great interest to spectroscopists, neocyanine, a dye obtained originally as a by-product in the synthesis of kryptocyanine, has proved very valuable, its normal spectral sensitiveness extending to 900 mμ, while by hypersensitizing and the use of long exposures, the infra-red line of mercury at 1014 mμ may be photographed without difficulty. Using this dye, Babcock has pushed the photography of the solar spectrum to 1163 mμ. The extension which has been achieved in the photography of the spectrum is illustrated in

LANDSCAPE PHOTOGRAPHED BY INFRA RED LIGHT USING A KRYPTOCYANINE PLATE.

the figure. New work in this field is proceeding continually but is slow and difficult.

The measurement of the color sensitiveness of photographic materials can be accomplished either sensitometrically or by means of a spectrograph. A simple grating spectrograph using a tungsten lamp as the source and a wavelength scale held in front of the plate so that it is impressed upon it at the time of photographing a spectrum is all that is required, but it is convenient to have a sector or a neutral tinted wedge in front of the slit by means of which a curve of the sensitiveness of the material is drawn automatically so that the position of the sensitive bands can be seen at a glance. For quantitative measurements a more convenient method of determining the sensitiveness is to give a graduated series of exposure through color filters transmitting known regions of the spectrum For this purpose exposures are usually made through the standard set of tricolor filters used for color photography, each of them transmitting approximately one third of the visible spectrum, their colors being orange-red, green and blue-violet. The characteristic curves obtained through these filters are usually of slightly different shapes and are rarely strictly parallel to one another, so that the sensitometric characteristics of a photographic material are dependent upon the wave-length of the radiation producing an image. No general principles can be laid down as to the variation of gradation with wave-length, the effect depending upon the particular emulsion and sensitizing dyes which have been employed.

One of the most important applications of photography in science is to photometry, and no account of the sci-

ence of photography would be complete without some mention of the photographic methods of photometry.

These methods can be divided into two classes: (1) those dependent on the increase in size of an image with increasing intensity or exposure time; (2) those dependent upon the increase of the density produced in an area of some size. The first method is that used by astronomers in what is known as the "focal method of the photometry of stars," the diameter of the star image being measured.

When an artificial star is photographed in the laboratory with a series of increasing exposures, it is found that the relation between the diameter of the image d and the exposure is of the form

$$d = a + b \log E,$$

this formula applying with considerable accuracy through a range of exposures of one to several hundred. Over the very wide range of intensities used in stellar magnitude determinations, however, the astronomers have preferred to use the formula

$$\sqrt{d} = a + b \log I$$

which fits the measurements better for greater diameters of the image, though for images of the smallest diameters it does not fit so well as the first formula. The value of the constants a and b is determined on plates exposed to stars of known magnitudes, the unknown stars being interpolated upon the curve. This method of photometry, which depends upon the diameter of the image, is very valuable in astronomy but of little use in other branches of physics, its application even in spectroscopy being pre-

LANDSCAPE PICTURE SHOWING THE BRIGHTNESS OF VARIOUS PORTIONS OF THE SCENE AS MEASURED BY A PHOTOMETER AND RECORDED IN METER-CANDLES.

vented by the varying width and sharpness of spectral lines.

For most physical purposes it is necessary to use measurements depending upon the density of the image produced, these densities being then interpolated on a scale of densities produced by known exposures. It is obvious that the accuracy of photometric measurements made in this way will depend upon the production of the scale of densities by known exposures under conditions which are exactly the same as those under which the densities to be measured are produced. We must eliminate (1) variations owing to the material, *i.e.*, irregularities in sensitiveness, thickness of coating, etc.; (2) variations owing to the treatment, *i.e.*, differences in developing the intensity scale and the densities to be measured, (3) variations in the intensity or time of exposure of the two scales (it is not justifiable to assume that time and intensity, the two components of exposure, are reciprocally equivalent); (4) variations owing to the quality of the light. The scale must be made by light of the same wave-length as that which produced the exposures to be measured. Provided that these precautions are taken, the methods of photographic photometry are capable of giving results of very satisfactory accuracy while the convenience of the method is unquestionable

The application of photographic methods in scientific research will undoubtedly continue to increase and will be of greater value if at the same time a knowledge of the science of photography becomes more widely diffused, since only by that knowledge can photographic methods be most efficiently applied

MORE SPIDER HUNTERS

ACCOUNTS OF ARACHNIDS WHICH ATTACK AND DEVOUR VERTEBRATES OTHER THAN FISHES

By Dr. E. W. GUDGER

AMERICAN MUSEUM OF NATURAL HISTORY

Introduction

In other articles (*Natural History*, 1922, Vol. 22, No. 6 and 1925, Vol. 25, No 3) I have reproduced with figures accounts of spiders which have sought out, attacked, killed and ofttimes eaten fishes, tadpoles and frogs, lizards and snakes, birds of various kinds, and, among mammals, bats and mice. Having lately gone into the literature carefully, I have found a large number of additional accounts. Those for the fishes have been set out in a paper recently published (*Natural History*, 1931, Vol. 31, No. 1), and now herein are collected additional and more voluminous data showing how spiders prey on all the vertebrates comprised in the groups from amphibians to and including mammals. These accounts definitely establish the fact that spiders, instead of feeding solely on insects, as they are supposed to do, also devour and, as is the case of some spiders, even prefer vertebrates as food.

Spiders Which Catch Amphibians—Tadpoles, Salamanders, Frogs, and Toads

In the first of my articles, there was given a quotation from a note on the fishing spider in the Argentine from the well-known naturalist, Carlos Berg. This article was also published in Spanish under the title "Una Araña Pescadora" in the *Anales Sociedad Cientifica Argentina* (Buenos Ayres, 1883, Vol. 15, p. 245). This spider, *Diapontia kochii* (a Lycosid), builds a funnel-shaped net in the water. When tadpoles enter the mouth of this, the spider drives them in farther, where it first kills and then eats them at its leisure

That spiders will attack salamanders is inferred from an observation by O E. Eiffe (*Zoologischer Beobachter*, 1909, Vol. 50, p 152). He had kept in an aquarium two axolotls which had developed from 50 mm (2 inch) larvae to the adult larval form One day his sons placed in this aquarium, without his knowledge, two water spiders (*Argyroneta aquatica*) Later he noticed one of the axolotls swimming around wildly in convulsions Examination showed no visible hurt of any kind The spiders were removed, but the salamander was paralyzed, presumably by the venom of the spider, and later died Unfortunately the spiders were not seen actually attacking the salamander, nor was experiment made to see if they would eat it.

One other published account must be quoted since it emanates from the station at Butantan, Brazil, where the celebrated snake toxicologist, Dr Vital Brazil, and his assistant, Dr. J. Vellard, have made experiments. A preliminary abstract appeared (in Portuguese) in *Brazil-Medico* in 1925 (Vol 39, part 2, pp. 47–51). The full paper appeared in the *Memorias do Instituto de Butantan* for 1925 (Vol. II) and 1926 (Vol. III). In the later volume under the heading "Alimentação" is found the data now to be set forth In translating the Portuguese, invaluable help has been had from an abstract of this in English by Dr. Alfranio do Amaral which has been published by the arachnologist J. H. Emerton in *Psyche* for 1925 (Vol 39, p. 60).

The spider experimented with is *Grammostola acteon* Pocock, a huge member of the family *Aviculariidae*, the male of which is 60 mm (nearly 2½ inches) long with legs nearly 3 inches long. A specimen kept in confinement steadily refused the insects offered it, but pounced upon a small frog, crushed it with its jaws and fed upon it. This spider feeds intermittently. One specimen was 48 hours in sucking a frog 60 mm (2.4 inches) long. Experiments with other frogs proved that the spider preferred them to insects.

In addition to the accounts quoted, Professor Alexander Petrunkevitch, of Yale University, has told me that in his boyhood, which was spent on the steppes of Ukraine, Russia, he saw spiders eat toads. This occurred in a clay pit dug down in the steppe about eight feet deep with practically vertical sides. Toads had fallen into the pit and had mined the sides near the bottom with holes in which they lived, while spiders of the genus *Lycosa* lived in holes at or near the mouth of the pit. The spiders would frequently descend into the pit and catch and eat the little toads.

Spider Hunters of Lizards and Snakes

The second of my papers quoted above (1925) contains an exact account of a spider's catching and eating a lizard in 1923.

This habit was, however, recorded long ago by Sir J. Emerson Tennent in his fascinating book, "Sketches of the Natural History of Ceylon," etc. (London, 1861, p. 469). In speaking of a huge spider indigenous there, he says that "a lady who lived at Marandahn, near Colombo, told me that she had, on one occasion, seen a little house lizard (*gecko*) seized and devoured by one of these ugly spiders."

All these accounts confirm an earlier one published in the *Journal of the Asiatic Society of Bengal* in 1842 (new series, Vol. 11, pages 860–861). This spider, studied in India, belonged to the genus *Galeodes*, whose members are all very voracious. Captain Thomas Sutton states that he saw a *Galeodes* spring on and sink its fangs in a lizard behind the shoulder. The lizard struggled violently, rolling over and over, but the spider kept its hold until the lizard succumbed. The body of the lizard, 3 inches long exclusive of the tail, was then entirely devoured. "The spider remained gorged and motionless for about a fortnight, being much swollen and distended."

Later a larger lizard was given this spider which seized it by the middle. The lizard, finding that it could not shake off the spider, bit the latter on the leg, which caused it to let go its hold. The lizard then got away and fortunately had received so little poison that it recovered. It may be noted here that the spider referred to was from 2½ to 2¾ inches long with a body the size of a thrush's egg.

Earlier, however, than any of these is a statement by Moreau de Jonnes in *Bulletin de la Société Philomathique* for 1817 (p. 135) that in the West Indies there is a large spider, the *Mygale aviculaire*, which preys on lizards of the genus *Anolis*. This brief account in the *Bulletin* is presumably an abstract of what is narrated at length in his "Histoire Physique des Antilles Françaises [Martinique et Guadeloupe]." (Paris, 1822). This is the earliest account known to me of a spider preying on a lizard. I regret that I have not been able to find the "Histoire" and that I am not able to give the full citation.

In addition to these old and somewhat indefinite accounts of spiders hunting down lizards, there is now this recent one from Zolton Szilady in Budapest (*Állatani Közlemények*, 1922, p. 42). He writes of the actions of a very

small spider, *Linyphia triangularis* as follows:

Last fall at Budafok I watched the struggle of a 5 cm [2 inch] young lizard, caught in a spider web stretched in the corner of my window. It was held by a few threads only, but the little spider worked rapidly and soon spun threads around its extremities. The gradual weakness of the lizard was noticeable in its struggling. Before the cobweb was completed, I put the spider into alcohol, released the lizard and tried to revive it. It moved after I tore the threads but died immediately after I was not present when the lizard was caught but according to the speed of the spider's spinning it must have occurred just before I came, so that the spider's poison took effect within three hours

Still later (1926) is the statement of Brazil and Vellard that their gigantic Grammostolas fed readily on chameleons and small lizards. They specifically note that a *G. acteon* caught a chameleon 350 mm (13.75 inches) long, driving its fangs into the buccal region and paralyzing it completely in three minutes.

These published accounts will now be supplemented by the following note communicated to me in manuscript by the distinguished arachnologist, Dr. Alexander Petrunkevitch, of Yale University. He writes that:

The number of authenticated cases of spiders caught in the act of feeding upon vertebrates may now be augmented by the addition of the following observation In January, 1926, Mr. Garcia of Rio Piedras, Porto Rico, who was at the time enrolled as a student in my course in Comparative Anatomy of Invertebrates, captured an adult female spider of the species *Heteropoda venatoria* (Linn.) holding in its mouth a small lizard of the genus *Anolis*. The lizard was dead and showed partial decomposition of its tissues, due not to decay but to the action of the digestive fluid of the spider. Mr. Garcia placed the spider and its prey in a glass jar and brought it to the laboratory to show it to me. In confinement the spider dropped the lizard and made no attempt to eat it again.

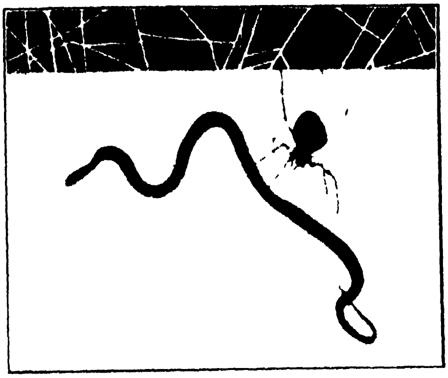
This case is interesting because *Heteropoda venatoria*, commonly called the huntsman spider, feeds normally on cockroaches and is for this reason tolerated by natives in their homes all over the tropics. It does not spin any snare, but captures its prey by suddenly leaping upon it. It is difficult to imagine that the spider was so hungry for lack of insects that it attacked a lizard, because insects were plentiful at the time in Rio Piedras. The huntsman spider is a night rover and hides during the day in dark corners of buildings, behind furniture, under roofs, etc. The chance of its meeting an *Anolis* is therefore very slight. But it seems probable that in case of such a meeting there is nothing in the way of preventing the huntsman spider from feeding upon the lizard.

That spiders will attack snakes was attested in my 1925 article by two accounts quoted. At the time I did not know that even in classical times this was known and recorded by the ancients But so it was, for Pliny in his "Natural History," Book X, Chapter 95, says that.

The spider, poised in its web, will throw itself on the head of a serpent as it lies stretched beneath the shade of the tree, where it has built and with its bite pierce its brain, such is the shock, that the creature will hiss from time to time, and then seized with vertigo, coil round and round, while it finds itself unable to take flight, or so much as to break the web of the spider, as it hangs suspended above; this scene only ends with its death

How accurate Pliny's account is may be seen in the reference next to be set out. This is a short article published in *Nature Magazine* for April, 1930. On page 234, Mr. E. Anderson describes how a small green snake once fell into the web of an orbweaver, *Epeira*, on his porch one afternoon. The snake threshed about wildly and tore the web considerably, but the sticky threads held him fast until "At last it hung quietly, securely fastened about his middle, and with a few stray meshes holding his head and tail."

The spider, which had been making ineffectual dashes at the snake, now sallied forth, wrapped the snake's middle in more silk and sunk his fangs in its body. Thus aroused, the snake struggled violently and would have broken away had not the spider repeated her performances of wrapping



—After Anderson, 1930 Nature Magazine

FIG. 1. A SNAKE CAUGHT IN A SPIDER'S WEB

HELD IN INVISIBLE THREADS, THE SNAKE IS BITTEN BY THE SPIDER, WHICH THEN RETREATS

and biting. The contest was kept up for about three hours at the end of which time the snake was sheathed in a silken shroud for nearly its entire length, and was nearly dead. The final outcome is thus described by the writer:

An hour later the snake was apparently dead, and the spider had begun to hoist her prey above the web. At supper time we noticed her feeding on the victim. Next morning nothing was left but the shrivelled remains of this large feast.

This contest is shown in Figs. 1 and 2 made from the original photographs which were kindly loaned me by Mr. Richard W. Westwood, chief of the editorial staff of *Nature Magazine*.

In addition to the foregoing, I have had the opportunity of reading the manuscripts of two other similar accounts of our native spiders and snakes, illustrated by photographs and drawings. Since these have not yet been published they can not be quoted herein. They serve to indicate, however, that this phenomenon is more frequent than might be supposed.

These snakes are merely ordinary ones, "garden varieties" so to speak, and one does not find it hard to believe the accounts of their capture. But there are now to be set out accounts of the killing of so poisonous, active and dangerous a snake as the rattler. The first account is from the pen of Dr. Arnoldo Krumm-Heller, writing from observations made during a residence in the state of Coahuila, Mexico. His article "Die Feinde der Klapperschlange" is published in *Kosmos*, Stuttgart, 1910 (Vol. 7, p. 417). He had been told of the enmity between the snake and a very poisonous spider, and one morning he had ocular evidence of the actual fact.

Seated on my horse [and looking over the landscape] . . . a spider about 5 meters away attracted my attention by its peculiar behavior. It would rapidly descend half way to the ground from a branch to which it always returned, thus indicating that the spot where it would have touched the ground was not wholly to its liking. Looking carefully at this spot I noticed a rattlesnake which appeared to be sound asleep. At once the stories I had heard came to my mind, and I knew what kind of spider I had before me. At last the creature seemed to have found a suitable spot on the branch, for suddenly it darted all the way down on its thread, bit the snake on the head, and then climbed as rapidly as before up to the branch. The snake for awhile remained quiet, but then became very restless, writhing from side to side and rattling with all its might until it became paralyzed from the quick action

After Anderson, 1930 Nature Magazine

FIG. 2. THE SPIDER HAS HOISTED HER PREY IN THE WEB

HAVING SECURELY ENMESHED THE SNAKE, THE SPIDER IS NOW READY TO FEED ON IT.

After Vital Brazil and J. Vellard, 1926

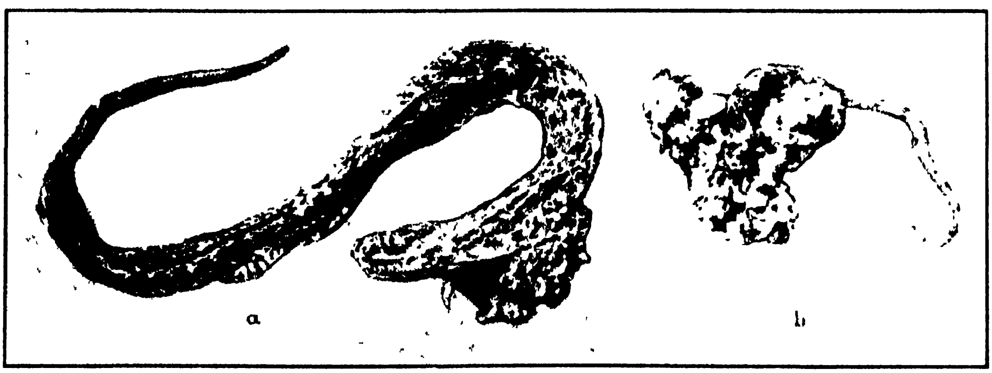
FIG. 3. A HUGE BRAZILIAN SPIDER FEEDING ON A SNAKE

Grammostola longimana OF SOUTHERN BRAZIL IS DEVOURING AN 18 INCH RATTLESNAKE, *Crotalus terrificus*

of the poison injected by the spider. The rattling of this snake grew gradually weaker, its movements slower and in less than a minute it was dead.

The attention of the reader is called just here to the marked similarity in the behavior of both spider and snake to that described by Pliny as far back as the beginning of the Christian era.

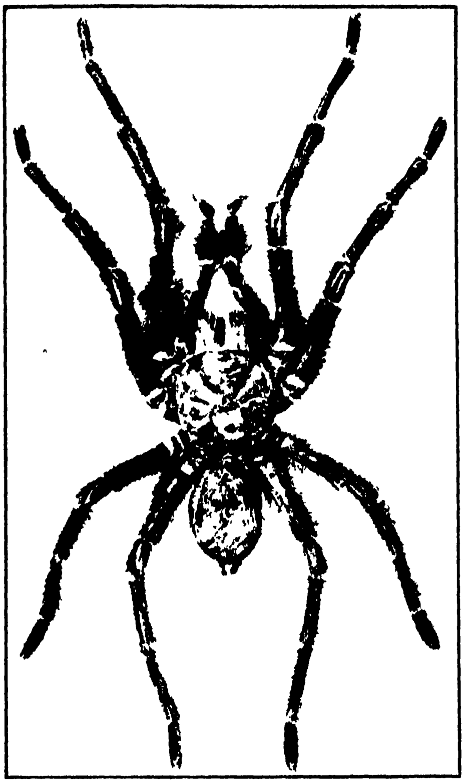
In the same year (1925) that my article was published citing accounts of spider snake-hunters, Drs. Vital Brazil and J. Vellard published an account of their experiments at Butantan with



—After Brazil and Vellard, 1926

FIG. 4. THE FLESH OF A SNAKE IS SLOWLY DISSOLVED AND SUCKED UP BY THE SPIDER

a. PART OF A SERPENT REJECTED DURING THE REPAST; *b.* RESIDUE ABANDONED AFTER THE REPAST.



After Brazil and Vellard, 1926

FIG 5 THE GIANT SPIDER, *GRAMMOSTOLA LONGIMANA*, OF BRAZIL, ONE HALF NATURAL SIZE

THE BODY OF THIS SPIDER WAS 55 MM (2 15 INCHES) LONG AND THE STRETCH OF ITS LEGS 203 MM (8 INCHES). IT IS ONE OF THE LARGEST SPIDERS IN THE WORLD. ITS FAVORITE FOOD IS LIZARDS AND SNAKES.

spiders and snakes. Dr Amaral's abstract in *Psyche* reads thus about the Aviculariid spider and a snake.

> When a Grammostola and a young snake are put in a cage together, the spider tries to catch the snake by the head and will hold on in spite of all efforts of the snake to shake it off. After a minute or two the spider's poison begins to take effect, and the snake becomes quiet Beginning at the head, the spider crushes the snake with its mandibles and feeds upon its soft parts, sometimes taking 24 hours or more to suck the whole animal, leaving the remains in a shapeless mass

Their figures showing these processes are reproduced herein. The first shows the Grammostola attacking a young rattlesnake, the second represents the partly eaten snake and the inedible parts of the snake when feeding had been finished.

Brazil and Vellard further say that if spiders are put in a large cage with insects and with snakes 10 to 18 inches in length, they will generally pay no attention to the insects. In the matter of voracity, these authors state, that two days after eating a 2½-inch frog, one of these spiders ate a small rattlesnake (*Crotalus terrificus*), the third day a frog, and the next day a jararáca snake (*Bothrops jararaca*) after which it went into retirement and fasted for two weeks while recovering from its orgy.

Brazil and Vellard finally state that by giving to the Grammostolas snakes and other cold-blooded vertebrates (frogs and lizards), they were able to keep in good health for more than eighteen months 50 specimens of these arachnids not counting a considerable number sacrificed from time to time to furnish the poisons necessary for their many experiments—all of which are set out at length in their 1926 paper.

From a perusal of the data set forth by these scientists, one must judge that in southern Brazil these very abundant giant spiders with a marked predilection for preying on frogs, lizards and snakes must act as an effective check on the multiplication of these cold-blooded vertebrates. This idea is emphasized when one examines Figs. 3 and 5, in which are shown *Grammostola longimana*, half life size. In life, the body proper is 56 mm (2 2 inches) long, and the reach of the extended front and hind legs is 203 mm (8 inches).

Birds Preyed on by Spiders

It is interesting to note that there are more references to the catching of birds by spiders, either by means of their webs or by pouncing on them, than there are to the catching of any or al-

most all other vertebrates by spiders. This is probably due to the fact that birds are plentiful, are always on the wing, and may readily dash into the almost invisible webs, or that the young in their nests are easily found and attacked by spiders.

That there are spiders' webs so large and strong as to catch and securely hold birds is amply attested by numerous references briefly cited by me in articles published in the *Bulletin of the New York Zoological Society* for 1918 and 1924, wherein I described the use of such webs for making fishing nets. To these might be added numerous like accounts which have since come to hand. It does not seem necessary to multiply these, but two accounts will nevertheless be referred to since they explain in detail how the bird is caught and since one has an excellent illustration showing just how the capture is generally effected.

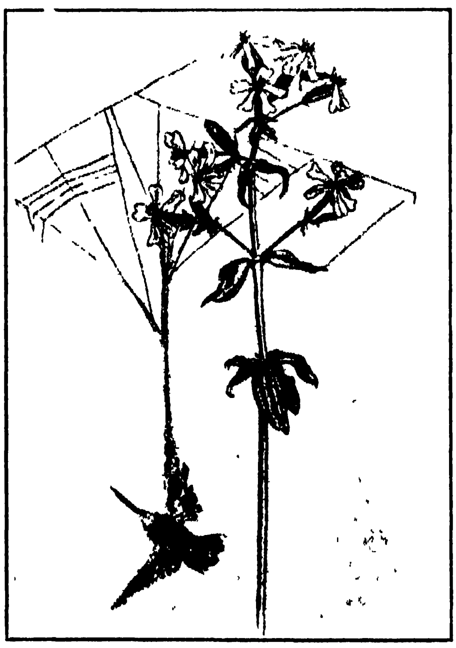
The accompanying illustration (Fig. 6) is taken from a note by S. D. Kirkman in the *New York State Museum Bulletin* for 1925 (No. 260, pp. 34–36). His very clear explanation is that:

> The bird had evidently flown into the web which it had completely demolished in its efforts to escape, but the strands had adhered so firmly to the tips of the primaries of the right wing that it was securely held and fluttered vainly, tethered to a stalk of Bouncing Bet from which it was suspended, not more than 18 inches from the ground. The gossamer threads had coalesced into one stout cable, very glutinous with the combined viscid drops of the web, and remarkably strong.

The bird had dashed into the web, where possibly the spider had tried to further ensnare it. The bird was completely exhausted by its struggles and unaided would never have escaped. This formation of a cable, it may be noted, is just what has been described in almost all accounts of birds caught in webs in which they struggle violently and twist the web into a cord. Moreover, this was also found in the case of snakes and mammals referred to in my 1925 article.

A similar state of affairs for a vireo found near Bardstown, Kentucky, is described by C. W. Beckham (*The Auk*, 1888, Vol. 5, p. 115). So exactly similar were the two phenomena, that if a vireo were substituted for the humming-bird above, the figure could be used to illustrate the second account.

The distinguished student of spiders, Henry C. McCook, in Volume I of his great work, "American Spiders and Their Spinningwork" (Philadelphia, 1889, p. 234), quotes two accounts of such happenings reported to him by trustworthy witnesses. In the first case a kingster became accidentally entangled, but in the second the spider was seen further to enswath her victim,



—*After Kirkham, 1925*

FIG. 6. A HUMMING-BIRD SNARED IN A COBWEB

THE BIRD IN ITS EFFORTS TO ESCAPE HAS TWISTED THE WEB INTO A STRONG CORD WHICH HOLDS IT FAST. THIS IS A COMMON OCCURRENCE WHEN SMALL BIRDS ARE CAUGHT IN WEBS.

— After J. G Wood, 1923

FIG. 7. THE *MATOUTOU* OR "CRAB SPIDER" (*MYGALE CANCERIDES*) OF THE WEST INDIES

THE SPIDER HAS CARRIED THE YOUNG HUMMING BIRD FROM THE NEST AND HAS SUNK ITS FANGS IN THE BIRD'S BODY

and when released the poor bird was dead. It seemed evident that this spider (an *Argiope*) purposed to feed on her prey.

However, most of the bird-catching spiders make either no webs or very small ones, but rather hunt for their prey and catch it by leaping on it The accounts now to be considered consist mainly but not exclusively of these.

The general works on the Arachnida for the most part contain statements that spiders catch and eat birds. These will be disregarded, however, and citations will be given only to first hand accounts. It may be stated, however, that when this phenomenon was first alleged it was very much scouted at. Something of this may be found in my 1925 article in which I showed that spiders catch and eat birds This much debated matter was absolutely established from H W. Bates' "Naturalist on the River Amazon" (1863), but I have since found that his observations were originally published in the *Zoologist* for 1855 (Vol. 13, p. 4800)—to which the interested reader is referred. In this article he expresses his belief that spiders living in the sandy *campos* around Santarem, Amazonas, must feed on birds and on lizards also since there is no other food for them.

Earlier, however, W. S. MacLeay had

described in the *Annals and Magazine of Natural History* (1842, Vol 8, p. 324) how, near Sydney, New South Wales, he had seen suspended in the web of an enormous spider, belonging to the family Epeiridae, a half-eaten fledgling of *Zosterops dorsalis.* The bird had been dead two or three days, but when observed the spider was in the act of still sucking its juices. MacLeay further states that his father had also previously witnessed another like scene.

Two men have by direct experiment long ago proved that spiders will attack birds. Thus, as early as 1832, Captain Thomas Sutton at Mirzapore, India, experimented with a huge *Galeodes.* Here is his account, written as a result of reading MacLeay's article just noted This he published in the *Journal of the Bombay Natural History Society* in 1842 (see citation above).

A young half-grown sparrow was placed under a bell glass with a fierce *Galeodes.* The moment the luckless bird moved, the spider seized it by the thigh. Then it transferred its hold to the bird's throat, and quickly killed it. It did not, however, devour any part of the bird, seeming to be content with having killed it. Since other bird-catching spiders devour their prey, and since this genus also eats lizards, it may be conjectured that at this time it was not hungry.

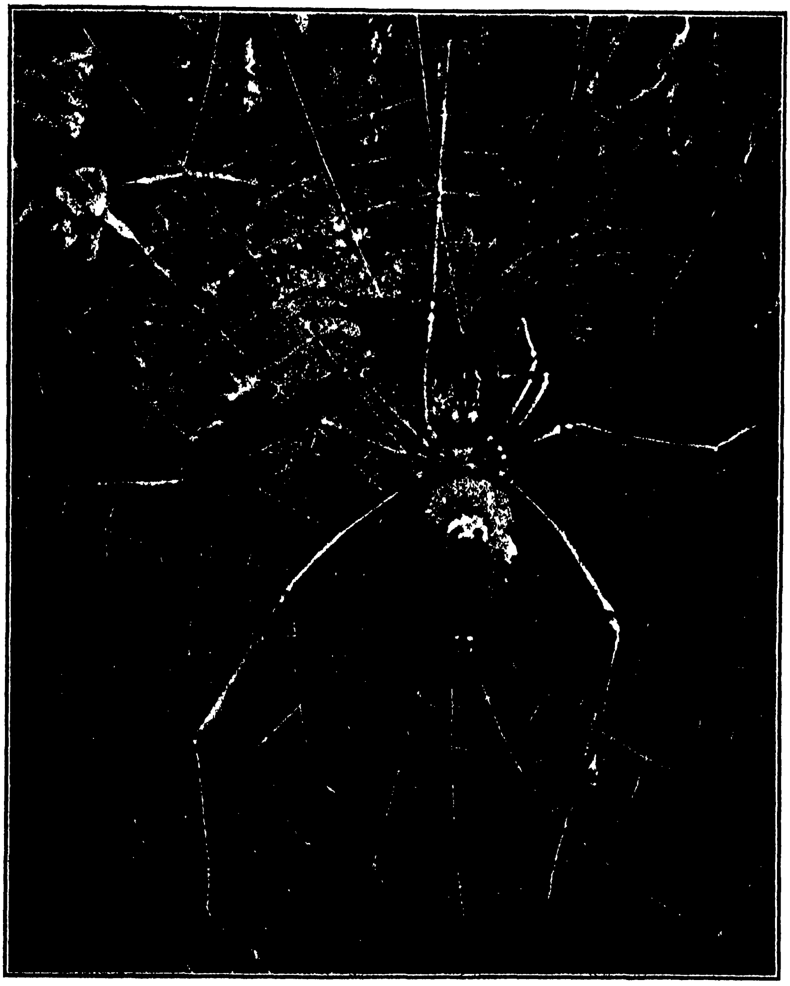
In 1857, C. L. Doleschall recorded in *Natuurkundig Tijdschrift voor Nederlandsch Indië* (Deel 12, p. 157) the result of an experiment he had tried with a giant Javanese spider, *Mygale javanica.* In order to let its poison be full in quantity and toxicity, he kept the spider in a suitable box for several days without food. At the proper time he introduced into the box a freshly caught rice bird. At once the spider sprang on it, embraced it with its feet and sank its poison-bearing fangs deep into the region of the spinal column. Within 30 seconds the bird died in a tetanic spasm. The spider at once began sucking the juices of its prey.

The oldest account for the Indian region of a bird-catching spider—this time a web-maker—dates back at least to the beginning of the last century. Robert Percival in his "Account of the Island of Ceylon" (2nd ed., London, 1805) on page 318 speaks of a huge spider with legs at least 4 inches long which makes webs "strong enough to entangle and hold even small birds which form its usual prey."

For the East Indian Archipelago, Mr. R. I. Pocock of the British Museum (Natural History) writes (*Annals and Magazine of Natural History,* 1899, Vol. 3, p. 83) that "In Borneo Mr. A Everett captured a specimen of . . . *Phormingochilus tigrinus* in a bird's nest where it had killed the young bird." From this one may judge that the specific name is justly applied to this spider. This statement is also found in the *Journal of the Bombay Natural History Society* for the following year (1900, Vol. 13, p. 121).

From another part of the world, the West Indies, there is another early account of spiders preying upon birds. Moreau de Jonnes, in the works previously cited, says that the giant spider of Martinique and Guadeloupe (*Aranea avicularia* of Linné) preys on *colibris* (humming-birds) and on *Certhia flaveola* (a bird allied to the tree-creepers). J. G. Wood in his "Illustrated Natural History" (in the edition published by Dutton, New York, 1923, p. 742) illustrates this habit in a drawing reproduced herein as Fig. 7. This arachnid he calls the "crab spider" or "*matoutou*" (*Mygale cancerides*). A figure similar to this is also reproduced (p. 49) in Wood's "Our Living World," Vol. III (New York, 1885).

I have citations to a number of other alleged first hand accounts of spiders catching and devouring birds, but since



—After Ealand, 1921

FIG. 8. A BIRD CAUGHT IN THE WEB OF A HUGE MADAGASCAR SPIDER

THIS SPIDER, *Epeira madagascariensis*, SPINS SUCH STRONG SILK THAT EFFORTS HAVE BEEN MADE TO UTILIZE IT FOR COMMERCIAL PURPOSES.

I have not been able to locate the books and verify the references, they will not be given herein. I will, however, reproduce for completeness' sake the figure (Fig. 8) found on page 128, of C A. Ealand's "Animal Ingenuity of To-day" (London) 1921. Ealand gives no hint of the source of the picture, which is probably an artist's conception of a stated fact.

There is in Madagascar a huge spider (*Nephila madagascariensis*) called *Halabé* which constructs large webs of very strong threads. I have looked up a number of articles on this spider, but all that I have found is that its silk is so strong and beautiful that serious efforts have been made to collect and utilize it for commercial purposes. To this end very ingenious mechanical devices have been perfected to imprison and draw out from a battery of spiders and wind on a reel this strong silk. There seems to be little doubt that such a web as that fig-

ured could hold the bird shown. This is in contradiction to a previous opinion of mine (1925, p. 271) expressing doubt.

Last of all in this subsection I am privileged to quote a first-hand observation made by the well-known entomologist Dr. J. Bequaert at Barumbu, Belgian Congo, on September 2, 1913 He writes that:

> Walking in the forest, I noticed a large spider web of the usual orbicular and radiating type, but built of very strong, yellow, silky threads. A small bird flew into the web, where it got entangled and was unable to get free. The spider (probably of the genus *Nephila*), as soon as she saw what had happened, jumped on the bird.

Spider Hunters of Mammals

In my second article (1925) referred to above I quoted an account of the capture of a mouse in a spider's web. Since that time additional accounts have come to hand and have been verified.

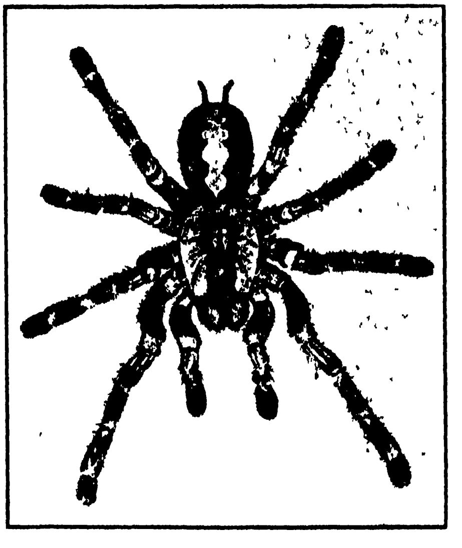
Pocock (quoted under the section dealing with birds), in his article on the habits, history and species of the giant spider *Poecilotheria* taken in the Madras Presidency of India, says that "it was, when captured, devouring a small rat which presumably it had killed." This account is also found in Pocock's article on "The Great Indian Spiders" in the *Journal Bombay Natural History Society*, 1900, Vol. 13, p. 121. Pocock's drawing (Fig. 9) of this beautiful spider is here reproduced. In natural size this giant is 60 mm (2.4 inches) long and the extent of its legs is twice as great (120 mm, or 4.8 inches).

That in India another huge spider feeds on another but rather nearly related mammal is found in an account which goes as far back as 1842. Captain Hutton, in the article referred to previously, describing the carnivorous activities of the spider, *Galeodes* (*vorax*) of Hindustan, says that "On another occasion, my friend Dr. Baddeley confined one of these spiders in a wall-shade with two young muskrats (*Sorex indicus*), both of which were killed by it." The spider, however, made no effort to devour its victims.

For this same animal, J. G. Wood in his "The Living World" (New York, 1885, Vol. III, p. 513) quotes a personal communication from Lieutenant-General J. Hearsey that:

> In order to ascertain whether the *Galeodes* would really attack and eat vertebrated animals, an ordinary-sized specimen was captured and placed under a bell glass. A very young muskrat was then inserted under the glass, the *Galeodes* being on the opposite side. As the creature traversed its transparent prison, it came suddenly on the young muskrat, which was quite a baby and could not open its eyes. Without hesitation it sprang on the little animal, killed it, and in a very short time had eaten it.

In similar fashion Braun describes in the *Zoologische Garten* for 1882 (Vol. 82, pp. 376–377) how an exotic Mygale of unknown country caught and fed



—*After Pocock, 1899*

FIG. 9. THE RAT-EATING SPIDER OF INDIA, *POECILOTHERIA REGALIS*, ONE HALF NATURAL SIZE

THE BODY LENGTH OF THIS SPIDER WAS 53 MM (2.1 INCHES) AND THE STRETCH OF ITS LEGS WAS 123 MM (4.8 INCHES).

upon mice in the zoological institute of the University of Würzburg. At intervals he placed in the cage with the spider young mice of two or three weeks old. The spider at once seized a mouse with its falces, and despite the efforts of the mouse to escape quickly killed it. Then the feeding process began. The spider covered the mouse with her whole body and for hours sucked its juices. This seemed to continue during the night, for by morning all that was left of the mouse was a globular mass of bones, teeth, hair, etc.—the insoluble residue after all the juices had been sucked out. This procedure was repeated a number of times.

In the 1925 article I described how both a snake and a mouse were lifted from the floor by a spider—the latter account was illustrated by a figure. Another like account (and a very recent one) has come to hand and is so interesting that it will be quoted verbatim. Mr. Guy Clagget writes thus in *Entomological News* for 1914 (Vol. 25, p. 230).

> An unusual thing . . . occurred at my home near Upper Marlboro, Maryland, a few days ago. A member of the family was attracted by a slight noise and upon investigating found under the sideboard a young mouse making frantic efforts to free itself from invisible bonds. It resulted that a spider, scarcely larger than a black ant, had caught the mouse and was performing an engineering feat that was truly interesting. This was the task of lifting the mouse from the floor to the bottom of the sideboard, a distance of about eight inches. The rodent kicked almost constantly during the operation, which lasted a little over three hours. The webs were then wiped away and to our surprise a second young mouse, dead, and completely swathed in web, was found.

In my second article referred to above, E. J. Banfield was quoted that on an island off the Australian coast a bat entangled in a spider's web was pounced on and killed by the spider. In "Our Living World" (Vol. III, New York, 1885), an edition of J. G. Woods "Natural History," revised by J. B. Holder, at that time a curator of the American Museum, is found another account. The spider, whose activities had been studied by General J. Hearsey (as noted previously in this article), is again referred to as follows:

> The same *Galeodes* was then pitted against a little bat, about three or four inches across the wings. Though small it was full-grown and lively. When placed under the glass shade, it fluttered about, but was speedily arrested by the spider, which leaped upon it, proceeded to drive its fangs into the neck, and clung so tightly that it could not be shaken off. In vain did the bat try to beat off the enemy with its wings, or to rid itself of the foe by flying in the air. Nothing could shake off the *Galeodes;* the long legs clung tightly to the victim, the cruel fangs were buried deeper and deeper in its flesh, the struggles gradually became weaker, until the point of a fang touched a vital spot, and the poor bat fell lifeless from the grasp of its destroyer.

Résumé

As a result of the data set forth in this article and in the three previous ones (1918, 1925 and 1931) by the writer, it is shown conclusively that among the invertebrate animals, spiders, previously held to be insect eaters only, catch and feed on vertebrates such as fishes, tadpoles, frogs, lizards and snakes, birds, and, lastly, mice, muskrats and bats among mammals.

HISTORICAL NOTES ON SALT AND SALT-MANUFACTURE

By Dr. L. G. M. BAAS-BECKING
JACQUES LOEB LABORATORY, STANFORD UNIVERSITY

"Salz und Brot gebet Gott"—salt and bread are gifts of the gods and belong to the most primitive economic goods known to mankind. The drinking water, made more or less immortal as an economic good by von Böhm-Bawerk, the grains and cattle, pet objects of the historical economist, and salt may be considered to be material bases of human society.

But while our knowledge of water, by continuous efforts of chemists and hygienists, has become increasingly deeper and fuller, while we have bred cattle and grains with scientific methods for quite a while, while we have studied their fitness and their value as economic goods by eliminating disease, by selection and by a study of their environment, our knowledge of salt is scant. From scores of laboratories information becomes available on our agricultural products; our water supplies are considered the very hearts of our cities, but the manufacture of salt is still, with minor modifications, at the same stage as it was at the time of the Emperor Huang, about 2,500 years before the Christian era.

The technologist might get impatient with this state of affairs—if he insists that there is a great opportunity here for economic improvement he is doubtlessly right—but to the student this stagnation in development has its great charms.

In studying this archaic salt-making process we meet often with things that have been the property of mankind for thousands of years. We feel as the encyclopedists did when towards the autumn of the eighteenth century they took stock of the French technology in their beautiful "Dictionnaire des arts et des métiers." While they struck the archaic in almost every technique, the historical harvest nowadays would be meager. It is not fitting to deplore this standardization of industry, for it would be the same as denouncing our very existence in modern society.

But when after Lavoisier the practical man began to employ the scientist as his helot, salt manufacture was fortunately forgotten. It remained forgotten until 1849, when for the first and the last time Usiglio evaporated sea water at Cette near the Mediterranean under uncontrolled conditions with the primitive chemical means of his day. Notwithstanding all the shortcomings of this work it will always remain a classic, as it inspired van't Hoff in his phase rule studies on the Stassfurt salt beds, gathered in two volumes in 1909 under the title "Zur Bildung der ozeanischen Salzablagerungen."

In the following paper I shall try to emphasize the historical conservatism in the salt industry and shall endeavor to show that a great many methods used in this industry are very old. Special emphasis will be placed on the organisms living in salt solutions of high concentrations, their influence on the industry and their antiquity.

I am painfully aware of the very incomplete account I have been compelled to patch together, and I sincerely hope that this paper may entice others to contribute their information on a most interesting topic.

The existing treatises on salt are, on the whole, economic in nature and do not give the technological and bacterio-

logical information which would make these works interesting to the scientist.

Historical Remarks

As late as 1665[1] we find a statement that the salt could be separated from the sea water by means of a "bladder made of wax."

This "bladder made of wax" was probably never tried experimentally because it was obviously cited after Aristotle, who, according to modern scholars,[2] depended upon an error made by a copyist, who substituted κήρινος (wax) for the κήραμινος (clay) in Democritus' writings![3]

Similar fanciful methods are still recorded in various seventeenth century journals. We shall pass, however, from alchemy to chemistry and start with the fathers of all culture—the Chinese.

The oldest Chinese treatise on pharmacology and pharmacognosy is the Peng-Tzao-Kan-Mu, which may be translated as the man-plant-classification. In this treatise, which dates back, according to some authorities, to about 2700 B. C., we find in Volume XI, on "Stones," part of Book V devoted to the description of "20 kinds of salt," and "27 additional kinds." The kind of descriptions and the style, especially of the chapter headings, are analogous to those of Dioscorides and Pliny.[4] In this book we find references to solar as well as to pit or rock salt (Fig. 1) manufacture. One fact is, however, apparent. *The solar salt is the oldest known in China.* The subject of the Emperor Huang, named Shu-Sha or Sou-cha, invented the art of extracting the salt from sea water.

This must have been prior to 2200 B. C., for we find that the Emperor Yu, of the Hia dynasty, which flourished during that era, levied the first salt-tax in the province of Tsing Tau.

Other processes of salt making in China are apparently more modern, for Li-ping, prefect of the province of Se-tchuan (300 B. C.), "well versed in the arts of stones," discovered in the earth the salt deposits. Exploited by means of salt-pits they enriched the inhabitants who previously got their salt from Chan-Si in exchange for their tea.[5]

The latter procedure is analogous to that employed in the Staffordshire brine-pits.

[1] *Phil. Trans.*, 1: 127 (anonymous).

[2] Compare, for instance, E. von Lippmann, "Abhandlungen u. Vorträge zur Geschichte der Naturwissen.," Chapter 11, pp. 98, 99, 162–199, 1913.

[3] This might be the earliest (though slightly warped) reference to "zeolithe" action!

[4] Compare Chapter 41, Book 31, of Pliny: "The various properties of salt: one hundred and twenty historical remarks relative thereto."

[5] See also le père Pierre Hoang, "Exposé du commerce public du sel," *Variétés Sinologiques*, Number 15, 1898, imprimerie de la Mission Catholique.

FIG 1. MANUFACTURE OF LAKE SALT BY BOILING. DRAWING AFTER A FIGURE IN THE PENG-TZAO-KAN-MU.

FIG. 2. MANUFACTURE OF SEA SALT BY BOILING. DRAWING AFTER A FIGURE IN THE PENG-TZAO-KAN-MU.

According to Hoang and to the Peng-Tzao two methods were used to extract the salt from the sea water.

1. In the province of Chi-Li ash from salt-plants is boiled in a kettle with sea water over a fire made of salt-weeds. The liquid is evaporated until an egg floats. Grains of the lotus, "che-lien," are also used. Twenty-four hours of boiling is sufficient to "grain" the salt. (See Fig. 2.)

2. In the province of Yai-cheau the following procedure is followed:[6]

> An embankment is made and ditches to draw clear sea water. It is left for a long time until the color becomes red. If the south wind blows with force during summer and autumn the salt may grain over night. If the south wind does not come all the profits are lost.[7]

The few citations above suffice as a starting-point for our considerations, for they contain a great number of points of general interest.

Shape of Crystal

In the first place it is worth while to consider the pictograms used by the early Chinese.[8] On Fig. 4, a, the archaic

[6] Literal translation by Mr. T. Hashimoto.

[7] Compare this statement with Pliny, Book 31, Chapter 41: "North-easterly winds render the formation of salt more abundant, but, while south winds prevail, it never increases," and also an anonymous letter to the Philosophical (later Royal) Society at London, dated September 20, 1669, and concerned with the solar salt process on the island of Rhé; "'Tis obvious, that the hottest years make the most salt; where yet it is to be noted, that besides the heat of the sun, the Winds contribute much to it, in regard that less salt is made in Calme, than in Windy weather. The West-and North-west Winds are the best for this purpose." Neither the recent papers of Tressler (see later) nor Peirce mention this factor (G. J. Peirce, "The Behavior of Certain Micro-organisms in Brine," Carn. Inst. of Wash. Publ. 193, 1914).

[8] The following information was obtained from Mr. Ninomya.

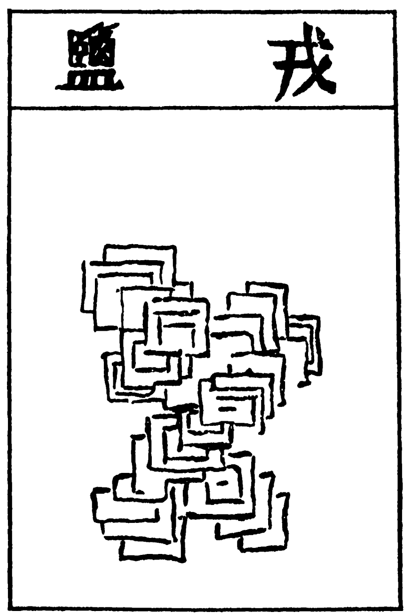


FIG. 3. SODIUM CHLORIDE
HOPPER-SHAPED CRYSTALS DRAWN AFTER A FIGURE IN THE PENG-TZAO-KAN-MU.

Chinese ideogram for salt (lu) is given. This undoubtedly represents a schematic picture of the so-called hopper-shaped crystal of sodium chloride, so conspicuous in solar salt works[9] (Fig. 3). Small coins in the shape of "salt-grains" were given to Marco Polo in exchange for gold.[10]

The Greeks and Romans[11] paid only cursory attention to the shape of the salt crystals, but the Chinese, with their innate feeling for stylization, have incorporated in their script what is probably the earliest picture of a crystal (compare also Fig. 4, d). We find a good description of the hopper-shaped crystal of salt in a paper by Robert Plot:[12] "They (the crystals) were visibly made up of a great number of small plates, shooting up from a quadrangular oblong Base into a very obtuse Pyramid, hollowed within."

The original ideogram soon was conventionalized and elaborated (Fig. 4, b). The little flag on the top may represent the salt-shovel. The modern character (Fig. 4, c) means "Imperial subject boiling salt in a pan," the person in the tail-coat being the imperial subject. This also refers to the fiscal aspect of salt manufacture. Until the recent up-

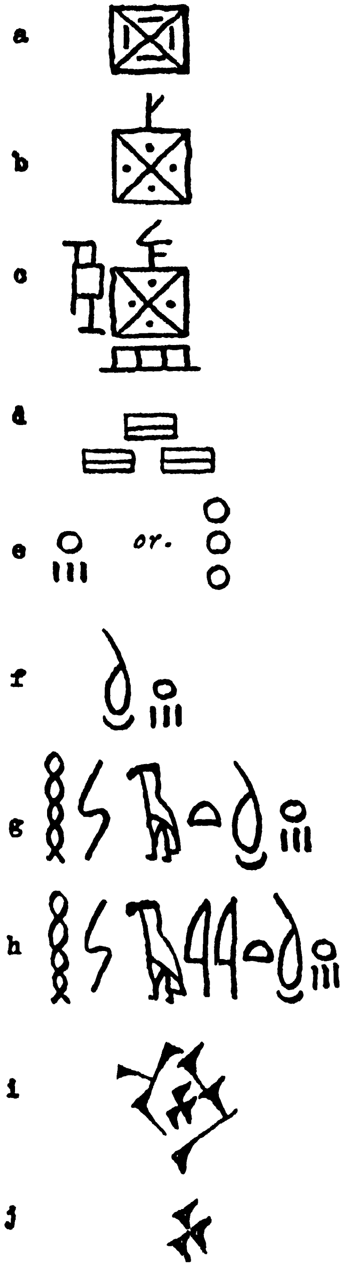


FIG. 4. CHARACTERS DEPICTING SALT

a, ARCHAIC CHINESE. b, CHINESE, LATER. c, CHINESE, MODERN. d, CHINESE: "TO CRYSTALLIZE." e, OLD EGYPTIAN: "MINERAL." f, OLD EGYPTIAN: "NATRON" *hsmn*. g, MIDDLE KINGDOM: *hmz̤.t*. h, LATER: *hmzy.t*. i. SUMERIAN: *mu-nu* OR *num*. j, SUMERIAN: LAND OR EARTH.

[9] For a description of its formation, see Donald K. Tressler, "Marine Products of Commerce," pp. 47–51, Chemical Catalog Co., New York, 1923.

[10] The relation between salt and money will not be dealt with in this paper; it should be mentioned, however, that the "Heller" is not the only coin named after salt. Our word "salary" means salt-money. See, for these and similar aspects of the question, Victor Hehn, "Das Salz," Borntraeger, Berlin, 1891; Margarata Merores, *Viertelj. Schr. F. Sozial u. Wirtschaftsgeschichte*, 13: 71–107, 1916; J. O. von Buschman, "Das Salz," 2 volumes, Engelmann, Leipzig, 1909.

[11] For instance, Pliny, Book 31, Chapter 39, "cube-shaped grains of Cappadocean salt."

[12] The contents of some letters from two learned and curious observers in Staffordshire, concerning the sand found in the brine of salt works of that country, *Trans. Roy. Soc.*, 13: 96, 1683.

heavals, China possessed a great hierarchy of salt-mandarins. Salt, being a necessity obtained in easily controlled areas, seemed the earliest fiscal prey.[13] Where the monopoly was confined to rock or desert salt, the dominating caste (such as the Egyptian priests) made active propaganda to discourage the production of sea-salt.[14]

The old Egyptian pictogram for "mineral" is given on Fig. 4, e.[15]

Sea Salt and Mined Salt

It will be noted that the Egyptian character for salt (Fig. 4, f) actually means "a specific mineral," a thing that is already there, that can be harvested from the Ouadi Atrun.[16] The same pictogram is affixed to the phonetic hieroglyphs on Figs. 4, g and 4, h. The only other character that yielded valuable information was the Sumerian *mu-nu* or *mun,* meaning salt (Figs. 4, i and 4, j). This character means "earth in a bowl" and points again to a terrestrial origin. Sea salt manufacture in the Mediterranean region seems to have originated with the Phoenicians. Ancus Martius (641–617? B. C.) is said to have founded the first Roman salterns near Ostia. The celebrated solar works at Setubal (the old Caetobriga) in Portugal are supposed to have been founded by Hasdrubal (third century B. C.).[17]

The remains of the Cartagian salt works at Salammbô are well known. The salt works at the mouth of the Dnjepr were already known to Herodotus (fifth century B. C.), and Pliny mentions sea salt from various sources. The most famous sea salt came from Citium on the island of Cyprus. This is the modern Lanarka or Scala. The salt works in this region, which are filled by seepage water through a narrow bar, are well described by Bellamy.[18]

The introduction of salt works on the Adriatic coast is of a much later date, the oldest Venetian Lease dating from 958 C. E.[19]

An anonymous author[20] gives a description of a solar-salt plant on the island of Rhé. Solar salt manufacture was introduced into the United States about 1830.

Leaching Method

Chinese influence pervaded the entire Orient. Cox and Juan[21] have given an excellent description of the primitive "leaching" methods and the evaporation method which are strongly reminiscent of the procedures mentioned in the Peng-Tzao. At the beginning of the Christian era, in the Gallic provinces and in Germany, it was the practice to pour salt water upon burning wood.[22] This procedure was also mentioned in a Frisian deed of 1258 (where burning peat was used instead of wood)[23] and still prevails in Transylvania and Moldavia. The salt-pit procedure mentioned in the

[13] See Merores, *loc. cit.*, on the influence of the salt-tax on the economic rise of Venice; also v. Buschman, *loc. cit.*, *passim.*

[14] According to Plutarch, the Egyptian priests claimed that sea-salt was filthy and unfit for consumption. They called it "Spume of Typhoon." Think also of the French "gabelle" and its preparatory influence on the French Revolution—and Ghandi!

[15] Information obtained from Dr. Baruch Weitzel and Dr. E. A. Speiser, University of Pennsylvania, *in litteris.*

[16] Herodotus, "salt of the earth," *i.e.*, the best salt from 'αλμυραξ, salt marsh. L. B. B.

[17] Information obtained from His Excellency Señor Jaquim Novais at Lisbon, through the mediation of the Hon. Samuel T. Lee, U. S. Consul-General at Lisbon.

[18] C. V. Bellamy, "A Description of the Salt Lake of Lanarca," *Quarterly Jour. Geol. Soc. London,* 56: 745, 1900.

[19] Merores, *loc. cit.*

[20] *Trans. Roy. Soc.*, 9: 1025, 1669.

[21] "Salt Industry and Resources of the Philippine Islands," *Philippine Journal of Science*, Sect. A, 375–401, 1915.

[22] Pliny, Book XXXI, Chapter 39, last part.

[23] "Quicumque foderit darigum [*i.e.*, "darg" or low-moor-peat] unde zel [read *sel*] per adustionem efficitur," *Oorkondenboek v. Holland*, 11: 1258.

oldest Chinese manuscript and used in ancient mines in Spain (Muria) and elsewhere formed the only way in which English salt was made in the seventeenth century. A great many historical data on these salt pits are available in the earlier issues of the *Transactions*. The Royal Society seemed interested in starting on a survey of economic resources and sent a questionnaire of seven questions to various "briners" to ascertain the methods of salt manufacture and the quality of the product obtained, especially as compared with the French salt. The results of this survey were a dozen papers which are of great interest as contemporaneous records. These papers form, in a way, the backbone for any historical study on salt. We will have occasion, therefore, to quote freely from them.

Specific Gravity

Let us continue to consider the statements made by the early Chinese. There it is said that the density of the first leach product had to be sufficient to "float a hen's egg" or to float a lotus seed. Thus we have a primitive aerometer which, after nearly five thousand years, is still used by every farmer who salts down pork! It was in use by the English briners in the seventeenth century. As I was unable to find in the literature the specific gravity of the egg, I determined the densities of a dozen fresh eggs and found them to lie between 1.071 and 1.080, average 1.074. This would correspond to a brine of 10–11 per cent., dependent, amongst other things of course, upon the depth to which the egg is submerged. Cox and Juan mention another primitive "aerometer" which is used by the Philippine briners:

> In Risal, Cavite and Bulacan provinces, it is a common practice to pluck twigs of the *culase* (*Lumnitzera racemosa* Willot), strip them of their leaves and throw them into the brine to test its strength. If they sink, the brine is not yet strong enough, but when they float, the brine is sufficiently concentrated to be transferred to the crystallizing ponds.

The density of the "culase" varies between 1.070 and 1.096. The average was 1.085, corresponding to 11.5 per cent. by weight of salt.

An interesting precursor of our pyknometric method is the attempt of W. Jackson in 1669 to determine the strength of a brine from his pits at Nantwich in Cheshire.[24]

He filled a bottle with 2 pounds of water, and then the same bottle "to the same mark" with brine. The increase in weight was 3 ounces 5 drams. The specific gravity of the brine was, accordingly, 1001.18/907.18 = 1.105. Assuming 15° C., this would correspond to an NaCl concentration of 14.2 per cent. by weight, or assuming sea salt, 14.9 per cent. by weight (Usiglio). Jackson states that "this brine yielded a sixth part of salt by weight," which would mean 16.7 per cent., but inasmuch as his salt was presumably not dry, the determination seems to have been quite accurate. Quantitative data are very scarce in the older literature, the salinity being usually expressed as grains per wine quart. Pliny[25] makes an attempt to define a concentrated brine as follows:

> If more than one sextarius of salt is put into four sextarii of water, the liquefying power of the water will be overpowered and the salt will no longer melt.

Remembering that the sextarius is a volumetric measure and taking the density of NaCl as 2.174, Pliny's statement means that less than 54.3 grams of salt are soluble in 100 grams of water. Of course it will be quite a bit less, because of the air spaces in his solid salt. Therefore we regard his value as very satisfactory when we compare it with the actual value of the concentration limit at

[24] *Trans. Roy. Soc.*, 1669.
[25] Book 30, Chapter 1: 34.

room temperature, 34.5 grams of salt per 100 grams of water.[26]

Red Water

Returning to the Chinese manuscript, we find (in the description of the solar process) that the sea water is evaporated "until the color becomes red." It is interesting to cite, in this connection, D. K. Tressler:[27]

> As the concentration of the brine approaches saturation, the brine worms and algae die and the solution becomes pinkish in color, because of the growth of certain red and pink bacteria. The salt maker takes this change of color as an indication that the brine is ready to be transferred to the crystallization ponds.

The occurrence of organisms in highly concentrated solutions always comes as a surprise to many, for the preservative action of salt was known to the ancients.[28] Plutarch[29] states that νέκυες γὰρ κοπρίων ἐκβλητότεροι, but that salt adds "soul." Because of this ancient belief, people did not look for *organisms* in salt. Even Sven Hedin[30] says of the salt marshes of Nor: ". . . the waters sterile as a chemical solution."

We know now that concentrated brines harbor a multitude of organisms, both animals and plants. Their numbers are great. In a recent enumeration that I made, there have been over 30 different species mentioned in the literature, most of which I have seen. This number is exclusive of bacteria, whose numbers are comparable to the bacteria inhabiting more usual environments.

Although Dr. Tressler's account interests us primarily as another illustration of the archaic nature of the salt-making process, it requires amplification, primarily because it is one of the few statements in regard to red water that is fundamentally correct.

The literature on the nature of red water, red snow and red rain is vast and its discussion would lie outside the scope of this paper.

The recent appearance of papers on this subject[31] shows, however, that not all points in connection with these phenomena have been clarified by the older authors.[32]

This is particularly the case in the so-called reddening of the brines about which many opinions have been recently expressed.

The practical briner or industrial chemist will usually ascribe the color of the brine to iron hydroxide, although other mineral substances were also mentioned to me as the possible cause.

Teeple[33] claimed that the highly colored brine from Searles' Lake, California, owes its hue to an extract of the creosote brush (*Larrea mexicana*). A similar conclusion was reached by Lunge,[34] who claimed that the color of the Ouadi Atrun brine does not filter out. It shows "nothing" under the microscope and is "organic substance in solution."

[26] Pliny's recipe for artificial sea water is no more than a guess (1 part NaCl; 13 parts of water by weight, actual value 1: 28).

[27] "Marine Products of Commerce," p. 44.

[28] Peng-Tzao-Kan-Mu, *loc. cit.*

[29] Symposion, 1.4.3.

[30] See below.

[31] *E g.*, S. W. Martin and Th. C. Nelson, "Swarming of Dinoflagellates in Delaware Bay, New Jersey," *Bot. Gaz.*, 88: 225, 1929.

[32] A few outstanding papers on the subject published in the early nineteenth century are: (1) M. Joly, "Historie d'un petit crustacé auquel on a faussement attribué la coloration en rouge des marais salants mediterranéens suivi de recherches sur la cause réelle de cette coloration," *Ann. Sc. Nat.*, 2 Sér. Zool. XIII, 1840; (2) A. Morren and C. Morren, "Recherches sur la rubéfaction des eaux et leur oxygenation par les animalcules et les algues," M. Hayez, Bruxelles, 1841; (3) E. Grube, "Ueber Blutwasser, den Blutregen und den rothen Schnee," *Preussische Provinzial-Blättern*, Königsberg, October 16, 1840.

[33] John E. J. Teeple, *Ind. Eng. Chem.*, 13: 249, 1921.

[34] G. Lunge, "Acid and Alkali," Vol. 11, p. 58, ed. *B.*

The red color of some African lakes was recently ascribed to the extract of red flamingo feathers![35]

It seems advisable, in this connection, to mention my own experiences[36] in relation to the work of older authors and to segregate under various headings the causes, inorganic and organic, of the red or orange colored brines.

1. The only inorganic cause, as far as I know, of red brine is iron oxide. It is often visible as an orange-red fringe on the floating masses of salt; it may cover sticks in the salterns to a certain degree. Its occurrence is never, as far as I have seen, pronounced. There must be present a fair amount of colloidal (or dissolved?) iron in the brine pools, because of the large mass of hydrated ferrous sulphide, which invariably forms underneath the brine (see below). This colloidal iron, however, does not seem to influence the color to a large extent.

1a. Colors due to metallic sodium dissolved in NaCl were not observed in natural brines.

2. Pink, red and purple bacteria seem to be the chief cause of red brines. It is well to define the groups more clearly, as much confusion may result from the term "red bacteria."

2a. Facultative anaerobes, saprophytes, non-spore formers; pigment formation independent of light. This is the group of the so-called "codfish" bacteria, which appear in the brines when there is enough organic matter present. They have been known for a long time,[37] but the recent literature is extensive,[38] on account of the economic importance of these organisms and the other red saprophytes.

2b. The red yeasts.[38]

2c. Dark red colors are attributable to the purple bacteria, facultative saprophytes, unable to live without light under anaerobic conditions. They contain a green pigment which, upon decomposition, yields a brown, water-soluble product (Searles' Lake!). The organisms usually live close to a source of H_2S (usually the black mud) and often withstand high alkalinities. The red organisms in *trona* or *soda* ("niter" of the ancients, compare Jeremiah 2: 22 and Proverbs 25: 20) are almost always due to true purple bacteria. Pliny[39] states that the salt from Memphis (Egypt) is deep red; that from Centuripa (Sicily), purple. At another place he states[40] that the produce of the Egyptian niter beds is red. "The best 'nitrum' comes from Lydia, the test of its genuineness being its extreme lightness, its friability and its color, which should be almost a full purple." We are satisfied that this substance represents a mixture of sodium bicarbonate and sodium carbonate, for "it is a sudorific, used in making bread, makes radishes tender and to vegetables it imparts additional greenness." At another place Pliny mentions the fact that purple salt is used as a cosmetic and that the outside of the crystals is rapidly bleached by light. This is exactly what happened to crystals of NaCl (with adhering carbonates) from Searles' Lake, California, which were inside still a dark purple, because of the presence of a large *Thiospirillum!* Innumerable desert lakes around the Mediterranean are called "Red Lake." When those lakes are highly alkaline it is plausible to assume that their color

35 P. Walther, "Sodium Carbonate Minerals of the Mogadi Lakes, British East Africa," *Am. Mineral.*, 7: 86, 1922.

36 The author of this paper might have been inspired by Darwin's "Journal of Researches" (see Collier's 1910 edition, p. 82).

37 Donald Monro, *Trans. Royal Soc.*, 61: 567, 1771.

38 Compare H. Klebahn, "Die Schadlinge des Klippfisches," *Mitt. a. d. Inst. f. all. Bot.*, 4: 11, 1919, Hamburg.

39 Book 31, Chapter 41.

40 Book 31, Chapter 46. The various kinds of nitrum.

is due to purple (sulphur) and pink ("codfish") bacteria.

Mr. Hugh Todd in 1683[41] mentions what is probably an occurrence of purple bacteria.

> . . . Those that have boyled this brine (I had not time to try the experiment myself) say that it affords a great quanitity of bay salt, not so palatable, yet as useful as ordinary salt is. It tinges all the stones with a Red colour.

2d. Plants, or rather chlorophyll-bearing organisms, may be the cause of these red waters. One hundred years ago, when the French Académie asked for an investigation of the reddening of the salt marshes near the Mediterranean, a controversy ensued between Payen,[42] who ascribed the color to a small crustacean (see below), and Joly,[43] who referred it to the food of this crustacean, a small flagellate, already described by Dunal and also by d'Arcet in 1830. The orange color due to this organism is very characteristic. It was Teodoresco[44] who finally named the organism *Dunaliella salina.* It is, like all salt organisms, cosmopolitan and may be obtained from California salines.[45] Hedin[46] must have seen it in the Kisil-Kul, "whose water both in color and consistency bore a striking resemblance to tomato soup."

I was able to observe the form in salt obtained from Portugal, Roumania, Hungary, Brazil and Venezuela and various places in North America.

We have good evidence to believe that it was known (of course not as an organism!) to the ancients. Teodoresco[47] states:

> un trait caractéristique pour le *Dunaliella,* c'est l'odeur agréable de violette qu'il exhale; ce fait a été mentionné par la plupart des naturalistes, qui ont eu l'occasion d'observer cette algue; cette odeur ressemble beaucoup à celle des gozons de *Trentepohlia aurea* humectés et a, certainement, pour cause la présence de l'hématochrome.

Dunaliella salina has a very striking orange pigment throughout the plastid, while the related *D. viridis Teod.,* is green, except for the eyespot. *Trentepohlia aurea,* a yellowish-red aerial alga, is called by the Tyrolese "Veilchenstein."

Recent work of Dr. J. Smith[48] seems to indicate that ionon[49] may be formed by the oxidation of carotin.

Now it is significant to note that Pliny[50] mentions the Cappadocian salt to be "saffron-colored and remarkably odoriferous." This would probably mean the salt of either Lake Tatta (modern Tus-Chōllū) or of the lakes near the river Cannalas (modern Lamantia).

This statement by Pliny would be a clear indication of the presence of *Dunaliella* if it were not for an observation made by Dr. C. B. v. Niel and myself; namely, that when an alkaline brine containing a small amount (.1 per cent.) of peptone is heated without the presence of any organism, it gives off an agreeable smell, not unlike tuberose (reaction on indole, however, was negative). This odor, of course, is different from an "agréable odeur de violette"; but, inasmuch as Pliny is no more explicit in his descriptions, the point is not definitely proved.

2e. While no definite records are known to me, it seems possible that

41 An account of salt springs on the banks of the River Weare or Ware in the Bishoprich of Durham, *Trans. Roy. Soc.,* 14: 726, 1683.

42 A. Payen, *Ann. chim et phys.,* 2nd ser., 65: 156, 1837.

43 M. Joly, *Ann. Sc. Nat.,* 2nd sér. zool, 13: 1, 1840.

44 E. C. Teodoresco, "Organisation et Developpement du Dunaliella," *Beih. Bot. Centralbl.,* 181: 215, 1905.

45 G. J. Peirce, *loc. cit.*

46 S. Hedin, "Central Asia and Tibet," Vol. 1, pp. 46, 530, Hunt and Brachett, London, 1903.

47 *Loc. cit.,* page 229.

48 Verbal communication.

49 Active principle of the perfume of the violet.

50 Book 31, Chapter 41.

blue-green algae which also in brackish lakes[51] often assume bright orange colors (*Aphanocapsa,* etc.) may occasionally cause "red water" in brines.

Other Organisms in the Brine

Entz,[52] Namyslowski[53] and Florentin[54] working in Hungary, Poland (Wieliszka) and Lorraine, respectively, have contributed most of our knowledge on the colorless protozoa inhabiting brines. These protozoa are also cosmopolitan, as I have been able to obtain good developments of various forms described by the above-mentioned authors from Portuguese, Venezuelan and Californian salt. It is, therefore, not surprising that we find an account in the *Royal Society Transactions* of 1682 by "Two observing Gentlemen from Staffordshire" who, by means of Mr. van Leeuwenhoek's microscope, observed in a brine from Nantwich "small organisms, actively moving and of a size about of the smallest salt crystal." This probably refers to one of the numerous salt-protozoa, but probably not a *Dunaliella,* the color of which they would have mentioned.

Purification of Salt

Sea-salt as such is hardly fit for consumption. It contains large amounts of the chloride and sulphate of magnesia. It contains salts of iron and calcium. It is highly hygroscopic. The English pit-salt also contains a large amount of calcium salts (the "sand" of the briners). The salt obtained by the archaic Oriental process is a rather unpalatable product. During the evaporation large amounts of sulphate are reduced by bacteria, anaerobic saprophytes, which form, in combination with the iron, the black mud which consists of clay particles interspersed with a hydrated ferrous sulphide (hydrotroilite). This substance, obviously, should not be harvested with the salt (*purification by harvesting*).[55] The precipitation of the calcium, chiefly as the sulphate, mostly precedes the precipitation of sodium chloride. The sulphate of calcium forms colloidal solutions; these solutions are so stable that great oversaturation ensues and consequently a liquor high in calcium may enter the salterns from the pickle ponds. The brine, before it is allowed to crystallize, has to be cleared from the calcium sulphate ("sand") *purification by clarification.* If no fractionate precipitation (which is comparatively modern) is practiced, the final product contains nearly all the magnesium as chloride or sulphate. Because the magnesium salts are much more soluble than the sodium salts, a simple *purification by leaching* was (and is) practiced.

A. *Purification by harvesting.* This process chiefly pertains to the black mud, which is present in every saline, whether natural or artificial. When it is exposed to the air it oxidizes, giving off hydrogen sulphide which may be detected by the smell. It is not improbable that the old etymological relation between the word "salt" and "stench" in a great many languages (see Victor Hehn, *loc. cit.*) originated from the odor of the sulphide which always accompanies the saline. Pliny gives a very drastic description of the smell of certain salts, but it was not until the seventeenth century that Martin Lister, professor at Oxford, in presenting his de-

[51] Observed by G. M. Smith, G. J. Peirce and the author in Pyramid Lake, Nevada, November, 1926.

[52] Geza Entz, "Die Fauna der Kontinentalen Kochsalzwasser," *Math. u. Naturw. Ber. aus Ungarn,* 19: 89, 1901.

[53] B. Namyslowski, "Ueber halophile mikroorganismen," *Ac. Cracovie,* 88, 1913.

[54] E. Florentin, "Etudes sur la Faune des mares salées de Lorraine," thèse, Paris, 1899.

[55] Sometimes an algal mat (Microcoleus sp?) is carefully tended to prevent the mixing of the brine and the black mud. This procedure is mentioned by von Buschman (*loc. cit.*) for salines in Italy, France and Portugal.

scription of English salterns to the Royal Society (1683) gave us some interesting observations pertaining to sulphate reduction:

At Northwich in Cheshire upon the Weever in 4 Pits is great plenty of brine; it stinks of sulphur apparently in all the pits; it becomes atramentous with galls.

At Nantwich upon the same River is one very large brine-pit. This water also plainly smells as if it were corrupted, or like sulphur.

Weston brine-pit near Stafford. This water in the pit stinks like rotten eggs.

Droitwich. . . . The water of these pits stinks like rotten eggs, especially after Sunday's rest [aeration! L. B. B.] and will, if flesh be pickled in them, make it stink in 12 hours.

The "rotten eggs" is clearly a good reaction to H_2S; the reaction to iron is given in the words "atramentous with galls." Pliny[56] states repeatedly, in his "Natural History," the preparation of ink (atramentum), shoemakers' black (atramentum sutorium), etc., by means of copper sulphate or iron salts plus gall nut extract. Lister apparently has used this reaction to look for "alum," that vague classical mineral embracing nearly everything. He has given us, however, a good description of the sulphate reduction, which had to wait till 1894 when Beyerinck's genius elucidated the chemism of the process.[57]

The soluble sulphides will do no great harm in a process where the brine is evaporated in kettles. But where the salt has to be harvested with flat shovels from over a surface of "slutch black as the scuttle-fish" the harvesting becomes a fine art. In the paper on the solar salt manufacture in France, mentioned above (1669), it is stated by the anonymous author (p. 1027):

As to the Whiteness of salt in particular, there are 3 things to be considered: First, that the earth of the Marish be proper. Secondly, that the salt be made with good store of water. Thirdly, that the salt-man, who draws it, be dextrous. In this Isle the Rhé there are that draw very dark salt, and others, that draw it as white as snow; and so it is in Xaintonge. Chiefly care is to be taken, that the Earth at the bottom of the Beds mingle not with the salt.

Exactly the same procedure is followed in the salt harvest around San Francisco Bay. A good briner will harvest the largest amount of salt without disturbing the black mud. The rules of this game are indeed old!

B. *Purification by Clarification.* To remove colloidal matter from the brine, Agricola[58] gives a recipe which seems to work but the mechanism of which is fairly obscure. In stating the procedure used at Halle, he says:

From 37 dippers full of brine 2 cones of salt are made. To clarify, to 2 casks 2 dippers add 1½ cyathus of bullocks, or calf's blood. Boil one hour, stir, boil one hour more. Then add 1½ cyathus of strong beer.

Converting these measures we get that in Agricola's time (1556) *1 part of blood was added to 1500 parts of brine* to clarify. (The beer is probably used to hasten crystallization.)

In the article of W. Jackson, communicated to the Royal Society, 1669, we find that to 20 gallons of brine he added (at Nantwich) 2 quarts of blood. Of this mixture 2 quarts were sufficient to clarify 360 quarts of brine, which makes *1 part of blood per 1800 parts brine.* The procedure, therefore, remained the same for over a century! Later references are unknown to the author of this paper. The seventeenth century briners also used "strong ale" to "corn" the saturated brine.[59]

[56] Book 34, Book 35, Chapter 25.

[57] M. W. Beyerinck, "Ueber Spirillum desulfuricans als Ursache von Sulfatreduktion," *Centralbl. für Bakt.*, 11, 1: 1–9, 49–59, 104–114, 1895. Jackson (*loc. cit.*, 1669) also mentions, in the description of the Cheshire pits: ". . . a blackish slutch mixt with sand, which infects the whole spring (like the scuttle-fish) black, when 'tis stirred."

[58] Georgius Agricola, "De Re Metallica," Translated from the first edition, 1556, by H. C. and L. H. Hoover. Published for the translators by the *Mining Magazine*, Salisbury House, London, 1912. See Book XII, *passim*.

[59] Jackson, *loc. cit.*, 1669.

In 1756 M. Schlosser discovered in the brine pools of Lymington, England, a phyllopod crustacean which he described in an obscure, and to me inaccessible place.[60] Linné described the animal in his "Systema,[61] as *Cancer salinus*: "habitat in Angliae salinis Limingtonianis D. Schlosserus."

It has been reported from various places since. Pallas found it in European and Asiatic Russia, d'Arcet in Egypt and Tunis, Joly in France. We know now that the organism is perfectly cosmopolitan.

ARTEMIA SALINA

It is of common occurrence in every salt lake in which the salt concentration may become lower than about 4 per cent. by weight.

It is very improbable that this organism should have remained unknown so long. Our very imperfect knowledge of the literature and the unavailability of the chronicles of Arabian travelers, especially, may be the cause of this hiatus.

It is true that neither Greeks nor Romans mention the animal. It is used as food by many Arab tribes, probably since time immemorial. There is a lake in Fezzan called "Worm Lake." Beyond this I have been unable to obtain any information, but there is indirect evidence to show that the knowledge of this organism is old. It is well known to the briners, and the knowledge of the briners is archaic knowledge.

A few years ago the foreman of a near-by salt works came to our laboratory to ask for a few *Artemiae*. When asked for what purpose he wanted them, he declared that he could not make salt without the "brine-worms." As at that time we could not accommodate him, he planned to send to Great Salt Lake in order to get the desired organisms. At that time we thought the man foolishly superstitious, little realizing that these organisms were used by the old English briner[62] and called by them "clearer-worms."

Anselme Payen and Audoin in 1836[63] performed a few experiments which are very significant in this connection. While remarking upon the passive method of feeding of this crustacean ("Strudler" of the German zoologists), they tried to see what the organisms would do with fine suspensions of calcium carbonate (p. 223):

> Voulant alors essayer si l'on parviendrait à remplir leur tube digestif à l'aide d'un corps solide tres divisé, on mit plusieurs des petits Branchipes (Artemia) dans le même mélange non-filtré.

As a result, the Artemia clarified the water completely. Hence the name "clearer-worm." I have repeated this experiment with fine and rather stable suspensions of barium sulphate, calcium carbonate and calcium sulphate with the same result: the liquid which passes through their digestive tract is freed from its particles, which coagulate in small pellets. Five artemiae cleared a milky white suspension of barium sulphate (100 cc) in 24 hours while the controls remained unchanged. The pellets on the bottom of the jar contained the precipitated matter.

Van't Hoff[64] remarks that it is almost impossible to precipitate calcium sulphate from sea water at the concentration where it is due to precipitate. It may therefore very well be that *Artemia salina* by its incessant action has made salt manufacture possible.

C. Purification by Leaching. In the

[60] "Observations Periodiques sur la Physique (de Gautier), 1756.

[61] C. v. Linné, "Systema Naturalis," p. 634, 1758.

[62] See Th. Rachett, *Trans. Soc. Linn.*, 11: 205, 1815.

[63] Payen and Audoin, *Ann. de Sc. Nat.*, 6 (2 B ser.): 219.

[64] "Zur Bildung der Ozeanischen Sallzablagerungen," Jena, 1909.

Venetian (tenth century) salt works, the "ciuca" or "tumba," the salt pile was left a long time to leach in the rains. This improved the quality of the salt. The same practice is still followed in a great many recent plants, but the fact is already mentioned by Pliny![65] The salt loses a large amount of magnesium compounds, its hygroscopicity is reduced and part of its bitter taste disappears.

This procedure was also used in the seventeenth century in the French salterns.

65 Book 31, Chapter 40.

Conclusion

Salt is still made in a way reminiscent of antiquity. The sea water, at many places, still drawn up by means of Archimedean screws, evaporates. The "clearer worm" does its work. Then we wait for "red water" and pump into the saltern from this pickle pond. When the "hoppers" "corn," the liquor goes to the bitterns. Then in the saltern it is harvested, and the salt is scooped up carefully from over a layer "black as the scuttle-fish." The piles are set to leach and to bleach.

THE EVOLUTION OF THE CREATIVE IMAGINATION

By Dr. PAUL CHATHAM SQUIRES
CLINTON, NEW YORK

FRIEDRICH NIETZSCHE, in his "Birth of Tragedy," has written: "He who destroys illusion within himself and in others is punished by that most severe of tyrants, nature," for "it is part of the essence of action to be veiled in illusion."

In this striking passage the philosopher Nietzsche has expressed in poetic form a leitmotif of psychology. It is through the powers of imagination, of "illusion," that man has risen to conquer and reconstruct the world in which he lives.

The problem of imagination, then, is central for the understanding of mind at large. And since the operations of imagination are inextricably woven into the patterns of our daily existence, the layman may well pause to consider certain of them.

There is a scientific truism to the effect that anything, be it an organism or a star, can be adequately understood only in terms of its evolutionary story. The human body, for example, has come to be what it is only after having passed through an indefinitely long racial past. The star, also, goes through a number of more or less well-defined stages, each stage consuming eons of time. In every instance, whether the object of investigation be animate or inanimate, the endeavor must be made to comprehend the object in the light of its history.

And thus, when we come to ponder over the nature of imagination, the evolutionary point of view will be found absolutely indispensable. The beginnings of imagination in the human being, the main stages of imaginal growth, abnormal manifestations and the culmination in the loftier regions of creative imagination—these are the questions that here present themselves.

II

Through imagination we respond to things that are physically absent as though they were present. Through imagination man may free himself at will from the present moment and project himself into the future.

Prometheus scaled the heights of Olympus and stole the fire from the gods, giving it to mortals. And as by the gift of fire in the olden days man was in part liberated from the arbitrary dominion of the Olympian deities, so has he been emancipated from the bondage of the mere present by the gift of the imagination.

When one contemplates the great works of the creative imagination it is quite natural to feel that they are too complex, too subtle, for any analysis. But these monuments of science, art, literature or whatever else have not come into being at one blow, miraculously. They have a history back of them, whose tangled strands we may aspire at times to trace.

To begin with, by way of a preliminary and very general reply to this question of origins, a famous maxim of psychology may be paraphrased to run as follows: There is nothing in the imagination that has not previously been in the senses.

Take the case of a man born completely blind. In neither the waking recollections nor the dreams of such a one can there be any visual experiences. His memories will be forever limited to the residues derived from prior contact with the outside world through the avenue of such sense organs as those mediating the sensations of sound, taste, smell, warmth, cold, muscular stresses and strains and a number of others which need not be mentioned.

But there will be no color, visual line or form in this man's memories. He may learn all about color, about the physical laws and mathematical equations of ether vibrations, but he will know not one bit more at the end than at the beginning of his studies concerning the visual universe as a directly given experience.

You will no doubt make the comment that anybody knows this to be so. Yet, there was a time when certain philosophers taught the doctrine of "innate ideas," that is to say, the doctrine that some of our ideas, at least, do not depend for their beginnings upon previous sense impressions, but are present in the individual at the time of his birth. Concerning such ready-made ideas modern psychology knows nothing.

Persistence along a line of action, even though the stimulus initiating the action has subsequently been withdrawn, is a universal characteristic of organisms from highest to lowest. It is an expression of the omnipresent law of inertia. The microscopic one-celled Amoeba, standing at the foot of the evolutionary ladder, evidences well the operation of this law.

The Amoeba is a cannibal upon occasion. Bring this animalcule into contact with a smaller one and the larger, if hungry, will try to "swallow" the latter. Provided the smaller eludes the first onslaught a lively pursuit frequently ensues. The larger Amoeba moves this way and that in a trial-and-error, but purposive, manner, striving to effect the capture of its prey. The chase may endure for a considerable time, notwithstanding that after the first collision the tiny organisms have not touched each other.

We have just witnessed a clear and unequivocal instance of the after-effect of stimulation in an extremely simple type of life. Let us now pass without further ado to the top of the ladder and observe an after-effect in a human sense organ.

It is a matter of common knowledge that, after having looked at an electric light, the after-image of this light may persist for quite a while. Perform the following easy but most entertaining and instructive experiment. Have ready in a perfectly dark room an electric lamp equipped with the ordinary opaque, rounded shade. Take some one into the room with you and instruct him to move his hand slowly and steadily back and forth. Directing the light upon the moving hand, flash it on and off for a dozen times or so, turning the light on for a couple of seconds and then cutting it off for three or four seconds. Keep your attention riveted on the hand. Finally, allow the light to remain turned off. A rather "spooky" thing will now be seen. To whatever part of the room your gaze may be directed, there, in the darkness, a ghostly hand is wafting to and fro. You are simply observing a version of what is called the positive after-image.

This sort of experiment is valuable in a number of ways. The main thing to be gotten out of it at the present juncture, however, is that when we look about us for the beginnings of imagination, we are at once forced to consider the more elementary inertial effects as they are to be found in a single sense organ, such as the eye. As concerns the lesson to be obtained from the behavior of the Amoeba, the instance brings home to us the fact that even at this lower level of animal existence the organism responds as though the exciting stimulus, physically absent, were present.

Having duly recognized this rudimentary form of memory, we will next make search for a type of after-effect a degree or so more advanced in the scale of mental development. In doing this we take the plunge into the fascinating topic of eidetic imagery.

It is sometimes said of a young child that he seems to be visually preoccupied. His play is apparently centered upon imaginary visual situations and things. The imaginary world has assumed for him the guise of reality. Are we to infer that he is imagining in the manner in which grown-ups usually do? Let us see.

During the past two decades some remarkable investigations have shown that a considerable proportion of children, and also some adults, possess the peculiar sort of imagination known as eidetic (from the Greek word *eidos,* meaning form). This eidetic imagination is strangely realistic; it is as though the person were "seeing things."

Present before an eidetic child a rather complicated pattern. After half a minute or so remove the figure. You will find to your surprise that the child can, even after a considerable lapse of time, reproduce it for himself with an astonishing degree of accuracy, especially if he is permitted to look at a neutral gray background. The pattern seems to be "out there against the screen." However, the child very early comes to understand that the object merely *seems* to be out there against the background, that he simply imagines it is there.

This vivid form of imagination has been thought to be a general property of childhood. Children utilize eidetic imagery in painting, drawing and in the making up of fairy-tales. The eidetic image arises not only spontaneously but may also, time and again, be called up at will. Girls have been supposed to possess the eidetic disposition more frequently than boys, also to be able to arouse the image at will better than boys. This fact of voluntary arousal is one of several marks by which the eidetic image may be distinguished from the ordinary after-image of sensation, which latter was illustrated above by the "ghost hand."

A process of selection is to be observed at work among eidetic images, and for that matter goes on at all levels of imagination. A person's interests determine to a large extent the degree of accuracy and stability with which the eidetic image is endowed. Thus, if a child is far more interested in birds than in butterflies, the images of birds will be more realistic in every way than those of butterflies, details of form and coloring being more photographically reproduced. In others, only the pleasing and the beautiful are retained in the image, the ugly and unpleasant features dropping out.

Although eidetic imagery quite typically wanes and decays after the age of puberty or thereabouts, notable exceptions are nevertheless to be found. There is little question but that the power of eidetic visualization has been rather common among great artists and poets. Michelangelo and Goethe, to give just two names, were undoubtedly "eidetikers."

Among the Indians of Spanish America there has existed from time immemorial a custom of chewing "mescal buttons." These are pills made of the drug peyote and give rise to visions of the most hallucinatory reality. The Indians, we are told, use this drug more particularly in their sexual orgies and religious rites. The disturbances of vision resulting from peyote have quite recently been subjected to investigation in the psychological laboratory, but it is not yet entirely clear as to whether by this means genuine eidetic images can be produced artificially in those who do not by nature have such imagery as a part of their mental equipment.

Although the overwhelming majority of research on this form of imagination has been done in vision, nevertheless there is eidetic imagery in other fields, such as hearing, smell, taste and pain. It need scarcely be pointed out how important eidetic imagery in hearing may

be for musical creation. Mozart, for one, must have possessed this faculty. Wagner is another probable instance, and others could no doubt be named. Incidentally, it is interesting to note that some people fail to get the eidetic experience unless one or more senses, in addition to the sense centrally involved, are simultaneously set into operation.

Investigation has of late been directed toward a more scientific approach to the problems of education through a recognition of the rôle played by eidetic imagery in the learning processes of the growing child. But as to the relation between grade of intelligence and degree of eidetic imagery, this is still a distinctly moot question, although some findings upon this subject have been published.

The medical profession, likewise, may at some future time benefit through the researches on eidetic capacity, if we are to believe certain investigators. The speculation has been brought forward that eidetic type may yet be made to serve as a practical index of the constitutional type to which certain patients belong. Actual studies have been carried out along this line. For instance, the relation between eidetic type and the incidence of goiter has been surveyed in a preliminary way. This matter, however, is still avowedly in the vague stage, although the lead is most attractive.

According to one famous theory the eidetic image is a transitional medium, a sort of missing link, both in the individual and in the history of the race, between the hitherto-described after-image of sensation and the more advanced memory image which we have yet to consider. Psychologists are endeavoring to interpret primitive art and language from the angle of the eidetic make-up, since the theory just indicated teaches that primitive man, as well as the child, must be presumed to possess the eidetic disposition. The interesting speculation has also been advanced that some animals show eidetic tendencies; if this were a fact it would constitute additional evidence bearing upon the theory in question, as pointing to the primal nature of the eidetic imagination.

The eidetic imagination, then, is outstandingly a fact of childhood. In adults it is the exception. This sort of imagination may be regarded as the means of preserving objects and situations in vivid and stable form until that period of mental development sets in at which the less realistic memory image common to adulthood, and abstract thought, take the place of the startlingly realistic eidetic image. The eidetic mechanism, therefore, is valuable as aiding in the survival and progress of the race and the individual.

III

The word image means a likeness. And as we sometimes say of a painting or photograph that it is the very image or likeness of a person, so mental images are the likenesses of previous sense impressions.

Moreover, just as the likenesses recorded upon canvas and film vary as to vividness, excellence of outline and accuracy of detail, so do mental images differ greatly in respect to the faithfulness with which they portray the original perceptions.

Eidetic images, as we have seen, serve as an intermediary stage between the after-image of sensation and the ordinary memory image. This latter memory image is to be distinguished from the eidetic image in a number of ways. For one thing, the common memory image is far less vivid, stable, real, than the eidetic reproduction; above all, it is localized not "out there" but "inside the head, I don't know just where."

However, we must not lose sight of the fact that although we talk now of the typical memory image common to

later childhood and to adults, and then again of eidetic images, nevertheless these classifications are merely so many emphases and do not after all carry us beyond the scientific preliminaries. The contents of consciousness are in never-ceasing flux and flow. There are all sorts and varieties of eidetic and other images. Some eidetic manifestations, for example, are intimately related to the after-image of sensation, while others stand near in appearance to the comparatively washed out and blurred memory image.

The main notion to be grasped here is that any classification, no matter how carefully worked out, is still ever short of its mark. The contents of nature and mind, especially those of mind, are not discrete and separated one from the other like beads on a string. Rather, all events form a dynamic continuity. They are so many transitions and transformations playing back and forth between poles which occupy varying positions.

Suppose we consider for a moment the importance of studying abnormal and diseased states of the imagination. How can this sort of study assist us to a better understanding of the normal imagination? The answer is not far to seek.

When a piece of machinery, such as an automobile, is running smoothly, one does not usually pause to examine the intricacies of the mechanism; the machine is simply taken for granted, like health. But when something goes wrong and we are thereby forced to make a search into the inner workings of the machine, we then begin to comprehend it.

There is a grave mental disorder known as paranoia, which irradiates socially devastating results. This unfortunate condition is marked particularly by delusions of grandeur or of persecution, ordinarily of both. The paranoiac may imagine himself to be a great scientist, artist, religious reformer, political figure, and so on in seemingly endless variety. Usually he believes that some one is scheming against him, is trying to undermine him, that all the world is plotting his downfall and destruction. Imaginary voices, sneering and accusing, or perchance exhorting to unparalleled accomplishment, follow him on his daily rounds. Joan of Arc, to mention just one famous historical case, is to be classed here.

Charles Dickens has given us a masterful portrayal of the paranoiac personality in his description of the father of the Marshalsea in "Little Dorrit." Mr. Dorrit's grandiose pose served as a defense mechanism compensating in part for the intense, agonizing feelings of social inferiority engendered by long years of confinement in a debtor's prison. His "superiority complex" acted as an antidote to the "inferiority complex."

This process of compensation is to be perceived in operation everywhere and at all times in the realm of mind. But in paranoia the compensatory mechanism is enormously intensified and exaggerated and hence stands forth dramatically for our better observation. In the paranoiac we witness the building up of an imaginary world to such an extent that the individual attains psychologically that which he can not seize in reality. The paranoiac condition represents a failure of adjustment to the environment, with all its stern realities. It is a flight from actualities. To be sure, there is an apparent exception to this interpretation in view of certain of our noted historical personages who have contributed so brilliantly to the progress of civilization in its manifold forms. But detailed study of these cases finally leads back to this principle disguised in more or less subtle manner, and materially aids in establishing it to be of universal scope.

The strange vagaries of the sexual imagination furnish another point of departure for clearer insight into the bizarre aspects and paradoxes of the life of imagination. Exhaustive delineations and interpretations of the sexual imagination cram the archives of the psychoanalytic schools. Dissection of the dream state has been of much value in this connection, for the dream may be looked upon as subserving a safety-valve function. Failure to secure satisfaction of the sexually toned wish in waking life on account of the sanctions of society, or for any other reason, is compensated for in part by wish-fulfilment in the dream. Thus, the dream acts as a temporary release for the surge of the suppressed desires which would otherwise wreck the organism. The individual, through the dream, obtains a respite from the torments of waking passion. The gift of imagination has come to his rescue, but only temporarily. For the dream is not the adequate solution.

In all the kaleidoscopic life of the imagination, no matter how simple or complex, whether in health or disease, the determining factor must not be allowed to elude our grasp. This factor is interest, feeling, emotional waxing and waning, call it by what names you will. And if the doctrine of Freud has any single, outstanding merit, it consists in the unstinted recognition of the dictatorship exercised by the feelings and emotions—in short, by the wish—over the imagination.

IV

So far we have been occupied mostly with the imagination in its reproductive rôle. But what of the creative imagination, to which the mighty works of science, art and philosophy owe their origins?

Inspiration, that is to say the creative imagination, transforms within its flaming crucibles the earthy elements derived from experience and ever reaches out beyond the confines of present, sensory experience. Copernicus surveyed the universe from the sun and a new world order sprang into being. Adams and Leverrier saw in the waverings of certain planets the heralding of a far distant heavenly body as yet hidden from the eyes of man. Laplace and Kant peered into the timeless past and gave us the nebular hypothesis. In all the gropings and strivings into the twilight of the depths of stellar space may be witnessed the powers of the creative imagination, eternally dissatisfied with the mere to-day.

The expressions of the creative imagination are as many as the needs and emotions of mankind. Voltaire, in saying that Archimedes must have been gifted with at least as much imagination as Homer, struck upon a fundamental psychological truth, for the imagination is just as surely active in the discovery of a crucial natural law or in the devising of a scientific hypothesis as in the writing of an epic poem, the hewing of a Laocoon out of a block of marble or the composition of a great symphony.

The popular notion has always seemed to be that the creative imagination brings forth something out of nothing. This is the mystic view.

To a scientific psychology, and to science in general, what is called creation (new-formation) is after all *trans*-formation. This is the meaning of evolution. Elements, previously given in experience, are recombined and altered so as to issue in novel patterns. And one of the greatest aids to a better understanding of the ways of the imagination is the study of the lives of the men who have wrought.

Here we can do no more than point at random to a very few works evidencing the activity of the creative imagination. We think at once of Kepler, laboring patiently for more than two decades in

his search for the laws of planetary motion. There is Lippersheim and the telescope which has resulted in an expansion of the universe. There are Galileo and the hydrostatic balance, Torricelli and the barometer, Pasteur and the insignificant-looking test-tube, the wonders of our wireless transmission with its manifold forms and uses. All these, and an impressive array of others, represent the gradual growths and the brilliant bursts of the creative imagination.

In the halls of ancient and modern philosophy we contemplate the magnificent constructions of Plato and Immanuel Kant, holding out to us world-frames and interpretations of human values.

In the domain of music, the heroic Beethoven uttering his Fifth and Ninth Symphonies, Chopin writing his unsurpassed tone poems, Schubert and the Erl King, Wagner in the home of the Valkyries, the magic Scherzo of Tschaikowsky's Fourth Symphony in pursuit of the lights and shadows—these are heights of musical creation that extend into the very empyrean. Here, if anywhere, does there seem to be a fashioning out of the void.

Then witness the grandest poem of all time, the Book of Job, with its awe-inspiring portrayal of a human soul in conflict. Behold the "Prometheus Bound" of Aeschylus, the inspirations of Milton and Dante and Shakespeare. Again, turn to "Les Misérables," with its sword-thrust into the social order of its day. In the world's great literature each one of us who will may live over the strifes and aspirations of gods and heroes and common men. Herein lies the secret of these works, that they compel us to identify ourselves for the time being with their life and action.

At last, behold the Faust in his old age. After a lifetime spent in futile pursuit of happiness, he finally turns to the gigantic scientific task of reclaiming vast expanses of land once inundated by the sea.

This feat, undertaken in the first instance to demonstrate the power of man over the hostile forces of nature, now becomes to Faust's clearing spiritual vision an undertaking for the benefit of the human race.

Below the hills a marshy plain
Infects what I so long have been retrieving;
This stagnant pool likewise to drain
Were now my latest and my best achieving.
To many millions let me furnish soil,
Though not secure, yet free to active toil;
Green, fertile fields, where men and herds go
forth
At once, with comfort, on the newest Earth,
And swiftly settled on the hill's firm base,
Created by the bold, industrious race.

Yes! to this thought I hold with firm persistence;
The last result of wisdom stamps it true:
He only earns his freedom and existence,
Who daily conquers them anew.
Thus here, by dangers girt, shall glide away
Of childhood, manhood, age, the vigorous day:
And such a throng I fain would see,—
Stand on free soil among a people free!
Then dared I hail the Moment fleeing:
"Ah, still delay—thou art so fair!"
The traces can not, of mine earthly being,
In eons perish,—they are there!—
In proud forefeeling of such lofty bliss,
I now enjoy the highest Moment,—this!

Thus, in man's unceasing struggle to attain mastery over the physical universe without him and the mental universe within him, he has passed from a relatively unconscious to a highly conscious "Will to Illusion." In the progressive victory over nature, in the noble structures of philosophy and literature and in the monumental works of art, we see the eternal strivings of the human spirit breaking free of its trammels through the genius of the creative imagination. For "it is part of the essence of action to be veiled in illusion."

SCIENCE SERVICE RADIO TALKS

PRESENTED OVER THE COLUMBIA BROADCASTING SYSTEM

X-RAYS AND THEIR USES

By Dr. F. K. RICHTMYER

PROFESSOR OF PHYSICS, CORNELL UNIVERSITY, AND CHAIRMAN OF THE DIVISION OF PHYSICAL SCIENCES OF THE NATIONAL RESEARCH COUNCIL

THERE is one invention yet to be perfected to make radio really successful from the standpoint of the speaker. For, I should like to ask those who are listening in this afternoon for a show of hands to ascertain how many of you have, at one time or another, had occasion to avail yourselves of the medical applications of x-rays. I did present this question to an audience which I was addressing some time ago and over 50 per cent. of the hands went up. Whether this proportion is typical or not, I can not say, but certain it is that a very large number of persons in this modern world have reason to be thankful to Wilhelm Konrad Röntgen for his discovery of x-rays. When Röntgen went to his laboratory that morning, some thirty-five years ago, to continue his experiments in electric discharges in rarefied gases, little did he dream that before nightfall he would accidentally stumble on a new agency which within the next generation would give to the medical profession a new tool destined completely to revolutionize certain phases of medical practice, such as—to mention only a few—the location of defective teeth; the diagnosis and reduction of fractures in bones; location of safety pins, bullets, marbles, or other trinkets in the human body; the observation of the complete digestive tract; and the treatment of goitre and various malignant growths.

These medical uses of x-rays are well known by everybody and, important as they are, I shall pass them by with only this comment: that if in 1894 some international medical society had offered a prize of $1,000,000 for an invention which should assist surgeons in setting broken bones it is a safe bet that not one of the aspirants for the prize would have been working in a physics laboratory with glass tubes, rarefied gases, electricity and the like—the paraphernalia which led Röntgen to his famous discovery. Truly scientific research pays large dividends.

Before discussing the other uses of x-rays, perhaps it is in order to say a word or two about their production and some of their properties.

If you examine the tubes in your radio set you will find that they contain a small filament, not so large as the filament of an automobile headlight bulb, which when heated by the electric current gives off electrons; that is, minute particles of negative electricity. This ability of certain heated bodies to emit electrons is the starting point of all radio sending and receiving sets. Without it, we should have no radio.

X-rays are produced in a highly evacuated glass tube or bulb in which there is a similar, but larger, filament. Now, everybody knows that positive and negative charges of electricity attract each other. In the tube opposite the filament is a metal terminal or target, frequently made of that very heavy metal tungsten, which is maintained at a very high positive potential, and which therefore powerfully attracts the electrons "boiled out of" the hot fila-

ment. When these swiftly moving electrons are suddenly brought to rest as they strike the target, they produce x-rays.

The process can be illustrated by an experiment which I wish to show you. I have here a tin pan and also a tin cup containing a pound or two of lead shot. When I strike the pan it emits a characteristic note like this (strikes pan gently several times): you can locate the tone on your piano.

Now I am going to hold the tin cup some three feet above the pan and slowly pour the shot into it. Listen carefully and don't mistake what you hear for static. Now: (pours shot into pan). If your ear is accustomed to analyzing sounds you could hear, amidst the rattle of the shot striking the pan, the characteristic note of the latter. In short, the sudden stoppage of the shot by the pan produces *sound waves* which are made up of a noise plus the characteristic note of the pan.

X-rays are produced in a somewhat analogous way. The tin cup corresponds to the filament of the x-ray tube. The shot corresponds to the electrons; the tin pan to the target; the force of gravity pulling the shot downward toward the pan is similar to the electric forces pulling the electrons toward the target; and the noise which you heard corresponds to the x-rays.

Of course, x-rays are not actually like sound waves; rather they are exactly like light waves, only of far shorter wave length. It would take about 50,000 light waves to make an inch; it would take 500,000,000 x-ray waves to cover the same distance.

X-rays in reality have all the properties of ordinary light. One of the most curious things about light is its ability to pass through certain substances such as glass, water, diamonds, etc. We are so accustomed to the fact that glass is transparent and that coal is opaque that we take it for granted. On the other hand, the ability of x-rays to pass through substances opaque to ordinary light is sometimes regarded as very strange. Actually, the behavior of x-rays is much more natural than is the behavior of ordinary light, for x-rays can pass through *all* substances, though in varying degree, some substances being more transparent than others. In general, the lighter substances are more transparent than heavy ones. Thus flesh is more transparent to x-rays than is bone; and accordingly when the röntgenologist takes an x-ray picture of a broken bone, the bone casts more of a shadow on the photographic plate than the flesh does. And hence we get the so-called x-ray picture which is really a shadowgraph.

This property of x-rays has led to a very important use in industry; namely, the examination of various engineering materials such as castings, and other metal or wood parts, that go into the making of automobiles, airplanes, and the like, to locate possible hidden defects. For example, a casting may be perfect so far as the appearance of its surface goes, but hidden within it may be blow holes, sand inclusions, porous regions or small cracks, which obviously unfit it for use. Such defective parts have been the cause of many fatal accidents. It is now possible to examine such castings, particularly the smaller ones, by means of x-rays, in exactly the same way that the röntgenologist examines a broken bone. And thus our automobiles, airplanes and high speed machinery generally may be made much safer through the agency of x-rays.

The study of crystals is one of the most far-reaching purposes for which x-rays have been used. After I have finished speaking, sprinkle a few coarse grains of common table salt on a piece of dark paper and examine them with a hand magnifying lens. You will ob-

serve that a great many of the grains are little cubes—in reality little crystals. Who has not observed the exquisite patterns of snow flakes? And who does not linger a little longer over the beautiful crystals in the mineralogical collections in our large museums?

Just as the magnifying glass makes it possible for you to see the individual salt grains, so the x-rays make it possible to study the exact way in which the atoms in each crystal are piled together to make the crystal. This is a fascinating study in itself and has led to results of great practical importance. For it has been found that not only are all materials, with very few exceptions, made up of little crystals, but that there is a close correlation between crystal structure and strength or other properties. For example, x-ray studies of crystal structure give very valuable information regarding the behavior of iron and the various steels as affected by rolling, drawing and heat treatment. The development of the process for making the tungsten filaments of modern incandescent lamps—without which process we should probably still be using the old carbon lamps—was essentially a problem in crystal structure.

In chemistry, x-rays have found many uses. You have all heard the answer which a certain lady received when she inquired of a chemist how she could ascertain whether her string of pearls were real pearls: "Put them in a glass of wine at night," said the chemist, "and if they are gone in the morning they were real pearls." The chemist, when he analyses samples by ordinary chemical methods, must of necessity destroy the samples. But by means of x-rays he is now able to make many kinds of chemical analyses without destroying or even altering the substances under examination.

The way in which this is accomplished is easily understood. Referring to our experiment with the shot and the tin pan: Suppose an assistant behind a screen had eight tin pans of different size each one of which emitted a characteristic note which, by previous test, you had located on the piano. By merely listening to the sound emitted when the assistant poured shot into a pan, you could tell which of the eight pans he was using.

Now, by means of x-rays it has been found that there are exactly 92 chemical elements, of which 90 are known. Each one of these elements, when struck by the electrons in an x-ray tube, gives out a group of characteristic frequencies of x-rays. By identifying the various groups of x-rays emitted when a sample of material of unknown composition is used in the target of an x-ray tube, the composition of the sample can be determined.

One of the most fascinating uses of x-rays has recently been discovered by biologists. It has always been a puzzle to know how the millions of different kinds of plants and animals originated. Some early students of evolution held that the polar bear, for example, developed a warm, protecting coat of fur because of the environment of the Arctic in which he lives. This view-point has been inverted by many modern biologists who now hold that environment is not the *cause* of the development of new species, but that, rather, the polar bear is able to live in the Arctic because, during the long process of evolution, he had previously been provided by nature with a warm, protecting coat of fur and was *able* to live in the Arctic. According to this view, new species of animals and plants arise from what are called "mutations"; that is, abrupt changes in characteristics. The offspring may be substantially like the parents for many, many generations. Then suddenly, and without any apparent cause, a new

species appears, differing from the parents in some essential characteristic. The sum-total of such changes or "mutations" over millions of years has, according to this view, resulted in the great variety of life which we find to-day.

But how do these mutations come about? It is just possible that through the agency of x-rays the biologist may be able to find an answer to this question. It has been found, rather recently, that the seeds of plants or the eggs of insects, if exposed to x-rays before planting or hatching, develop a far larger number of progeny differing from the parent than is found without such exposure. Here then the biologist has a new tool which appears to make possible the artificial production of new species.

Intensive studies of this new effect of x-rays are now under way, partly with the hope of shedding new light on the mechanism of evolution; partly to develop if possible new species of plants or animals of commercial value.

This new field of research bids fair to yield very startling and far-reaching results, but happily, there is no immediate prospect that the biologist, by a few doses of x-rays, will be able to turn monkeys into men, or vice versa.

Transcending all the above applications are the uses which the physicist has made in acquiring a deeper insight into the structure of atoms, the nature of radiant energy and the interrelations between these two entities which make up the entire physical universe. But this is too long a story to tell you this afternoon and hence I bid you "adieu."

THE EARTH AS AN ENGINEERING STRUCTURE

By Dr. WILLIAM BOWIE

CHIEF, DIVISION OF GEODESY, U. S. COAST AND GEODETIC SURVEY

HUMAN beings have lived on the earth for many thousands and possibly millions of years, but it is only within the last few decades that man has found out some of the essential and fundamental facts connected with the earth that are needed to discover those processes which have continuously changed the elevations and geographic positions of points on its surface.

The earth is not so mysterious after all, unless we acknowledge that all science is mysterious. If we use the fundamental principles of physics and engineering, we are able to attack and understand earth problems much more clearly than if we merely assume that the earth is a puzzle and that everything that is happening on its surface is mysterious.

There are some things that we know rather definitely about the earth—its shape and size, for example. These have been determined by very accurate observations made on the stars for latitude and longitude and by the measurement of distances between the astronomical stations by means of triangulation. As the distances are measured with great accuracy, the dimensions derived for the shape and size of the earth are correspondingly accurate. It is rather interesting to note that the most accurate determination of the dimensions of the earth was made by the Coast and Geodetic Survey. As they are the most accurate values known these dimensions have been adopted by the International Geodetic Association.

Another thing we know about the earth is its density, which is about five and one half times the density of water. The density of the surface rock averages about 2.7 times that of water. Since we know the average density of the earth

and its size, we also know its total mass. We know that the earth is not a stable structure—it is yielding continuously to forces which are acting on it. Areas that were once beneath the level of the sea are now high in the air as plateaus or mountains. We know this because fossil sea shells are present in these elevated rocks and it is certain that the amount of water on the earth's surface was never so great as to have stood at the elevations at which we find the remains of the sea animals. There are areas that once were above sea-level and had mountains and plateaus, which are now below the surface of the sea. There are areas where rocks are found which have been pushed horizontally for a mile or more.

The earth is subject to tremors from earthquakes, which occur at frequent intervals. An estimate has been made that there are approximately 8,000 known earthquakes every year. These are the quakes whose tremors are recorded on a very delicate instrument called the seismograph. There are not very many seismograph stations in the world, hence it is reasonably certain that if such stations were placed close together many more thousands of earthquakes would be recorded yearly.

There are many volcanoes on the earth's surface belching forth lava, rock and smoke. These volcanoes must be vents in the outer portion of the earth, which extend down to regions where the temperature is so hot that the rock is melted with the rupturing of the rock above.

We know that the temperature of the earth increases as one goes down from the surface. The temperatures at different depths are taken in mines and in wells that are drilled for oil or water. The increase in temperature with the depth changes from place to place, but the average is 1 degree Centigrade for about 100 feet in depth. If this rate continues down to the center of the earth, the temperature of the center must be many thousands of degrees. We do not know whether the temperature increases all the way to the center, but at least it must continue for some miles below the surface, for otherwise there would not be hot springs, volcanoes and outflowing lavas.

We know that at present there falls to the land area of the earth annually an average of about thirty inches of water in the form of rain. The time of the beginning of the formation of sedimentary rocks, according to the best estimate, was approximately a billion and a half years ago. There must have been rain at that time, for sedimentary rocks can not be formed unless there is running water. We may also assume as a certainty that at the beginning of the sedimentary age, a billion and a half years ago, the earth's surface was irregular, probably as irregular as it is today. If the rate of rainfall has been continuous during this billion and a half years, there could have been three quarters of a million miles of rain. When water falls to the earth as rain, it tends to go to lower levels, to the valleys and rivers, and eventually much of it goes back to the sea. This water carries with it in suspension and solution much soil and organic matter. It has been determined by the Geological Survey that the rivers of the United States in 9,000 years carry to tidal waters an amount of material in suspension and solution equivalent to a layer of earth one foot thick covering the entire country. This rate of erosion, or moving of material to tidal waters, may seem very slow, but it amounts to a mile of erosion in about forty-five millions of years. Since rain has been falling for approximately a billion and a half years, thirty miles of material could have been removed if for any area this rate has been maintained. Of course, no such amount of erosion could have occurred in any particular area.

The waters of the ocean, if spread uniformly over the whole earth, would be about 9,000 feet in thickness, somewhat less than two miles. This water has been used over and over again, thousands of times, during the sedimentary age in order to furnish the rain that has fallen back to the earth. This is the reason why the sea-water is so salty. Every bit of water that goes to the ocean has some solid matter in solution. During the evaporation this solid material is not taken up into the atmosphere but is left behind. Eventually the waters of the sea became saturated, as they are today.

The evaporation of the sea-water is necessarily due to the heat received on the earth from the sun, and we may therefore say that we shall have rain as long as the sun shines. When the sun ceases to exist, if ever, the earth will become an inert mass, because it will become extremely cold and there will be no evaporation and rain.

During the processes of erosion and transportation of material from the continents to the tidal waters, there is a disturbance of the equilibrium of the earth's crust—some parts are overloaded and other parts are underloaded. This causes a pressing down under the heavy weights of sediments, such as we have at the mouth of the Mississippi River and an elevation of areas which have been undergoing erosion, such as the Rocky Mountains, which have been made lighter.

It has been found by geodetic engineers working in different countries, but principally by the Coast and Geodetic Survey of the United States, that the outer portion of the earth, to a depth of approximately sixty miles, is composed of solid rock. This rock will break when forces are acting upon it for a long time, provided the forces are of sufficient strength. The interior of the earth, on the other hand, has been found to be composed of material that will yield like plastic matter to forces that are acting on it for long periods of time, say tens, hundreds or thousands of years. This interior material behaves like an elastic structure when forces are acting on it only for a short time. Such forces are the tremors that go out from an earthquake, and the tide-producing forces of the sun and the moon which change phase several times a day.

The result of this condition of a solid shell and a plastic interior is that under the heavy loads of sediments, which are deposited along the coast of a continent by its rivers, the solid material is forced down and the sub-crustal material is moved back towards the areas from which the sediments were derived. The outer shell, frequently called the earth's crust, rests on the interior material very much as a raft formed of logs rests upon a body of water. There is an equilibrium, established by the yielding to these loads of the outer shell of the earth, that is given the name "isostasy." This is a term derived from Greek words and it means "equal pressure" or "equal standing." The earth is in isostatic equilibrium, and whenever materials are moved over its surface by streams or rivers there is a tendency for the equilibrium to be restored. Of course, the earth's surface does not yield to very small loads—a few hundred or a thousand tons—or even to a few millions of tons, but after a river, like the Mississippi, has been sending solid material to the Gulf for a great many years, the crust near its mouth will be under such a stress that it will be pushed down to restore balance.

Since the temperature of the earth increases with depth, it is certain that the crustal material, which is pushed down under heavy loads of sediments, reaches regions which are normally hotter than the regions previously occupied. Eventually this crustal material takes on new temperatures and that causes an expansion that forces the earth's surface

upward. Here we have an explanation of the phenomena that earth's materials, once below sea-level, are now lifted high up in the air.

Where erosion has been going on for thousands or millions of years, the earth's crust will be pushed up to restore the isostatic equilibrium. During this process the crustal material will be raised into colder regions, and eventually it will be cooled down. This will cause a contraction and carry the earth's surface down, perhaps even below sea-level.

It would seem, from what has been said, that we must have four distinct causes of changes in the elevation of places on the earth's surface and of earthquakes. First, is the sinking of the earth's rocks under the load of sediments; second, the elevation of the crustal material as it is pushed upward under the area of erosion; third, the expansion of crustal material which has been pushed down by the sediments into hotter zones; and fourth, the cooling and contraction of crustal material which has been pushed upward under areas of erosion.

It will be seen that we have been treating the earth as an engineering structure, such as a bridge or a building. We can follow through some of the processes that are common to the physical laboratory and to engineering field work in the moving of materials of the earth. There is no such thing as a rigid earth. It is a yielding structure and it will continue to be a yielding one as long as we have rain and sunshine. It is very fortunate that the earth is not composed of material of prodigious strength. If it were, forces would accumulate until they overcame the strength of the earth's materials and then there would be an earthquake which would be vastly more destructive than those we are accustomed to. Strange as it may seem, the more earthquakes we have the safer we are, because the more we have the smaller will be the intensity of any one of them.

Earthquakes are caused by rock breaking, and what is called the epicenter, or point at which the break occurs, must be within about sixty miles of the earth's surface. It is reasonably certain that most of the earthquakes occur within thirty miles of the earth's surface.

We hear much about this or the other earthquake being more destructive than some other one, but we are very apt to rate an earthquake in accordance with the damage it does to human structures. An earthquake may occur in the center of a great desert and may create a great gap in the earth's surface, but may not destroy any human habitations because there are none near. Another earthquake of much less proportion may damage buildings and destroy human lives. The earth's surface has been subject to earthquakes for hundreds of millions or a billion of years. Since we can not prevent them we should apply our science and engineering to the problem of building our structures in such a way as to resist the shaking.

The earth will never collapse, but the mountains are not everlasting, and we will have earthquakes as long as the sun shines and we have evaporation and rainfall. Earthquakes will stop only when the sun no longer shines, but this probably will not occur for hundreds of millions of years. We must accept nature as it is, treat the earth as an engineering structure, and erect our buildings and other structures with a view to resisting those forces of nature which are constantly at work.

WHO IS THE AMERICAN INDIAN?

By Reverend JOHN M. COOPER

PROFESSOR OF ANTHROPOLOGY, CATHOLIC UNIVERSITY OF AMERICA

THE purpose of this short talk is to answer some of the questions that are more commonly asked about the American Indian.

We shall take up in turn his physical structure, his mental level, his languages and his culture.

Physically, the Indian is a member of the great Mongolian division of the human race. He shares with the Northern and Eastern Asiatic peoples their lank black hair, their yellow-brown skin, their broad face, and a number of other characteristics. In fact, there are some peoples living to-day in Northern Asia, who if transported into the midst of an American Indian Reservation, could not be distinguished physically from the Indians themselves. The Eskimo is merely a specialized variety of the general American Indian type, just as the Chinese and Japanese are specialized varieties of the Asiatic Mongolian type, or just as the tall, blond, blue-eyed Northern Europeans are specialized varieties of the Caucasian type.

Intellectually, the American Indian can not be proven to differ appreciably in average mental level from the white man. We have no conclusive scientific ground to show that the Indian is in the least inferior in average mentality to us of the white race,—if that is saying anything to his credit. Certain psychological tests, have, it is true, shown a gross margin in favor of the white man, but it is highly questionable what conclusions, if any, can legitimately be drawn from such gross differences in relative scores. These differences, so far as our present knowledge goes, may be due entirely to differences of social background, or of language, or to other factors that have little or nothing to do with basic intelligence proper. For instance, in one series of tests given recently, the Indian children examined ranked low on the proverb test but high on the story-memory test, both being tests of the Otis Group Intelligence Scale. These results are in all likelihood due not to mentality as such, but to differences in training, education and social background. The use of proverbs is a culture trait widespread over the Eurasiatic and African continents, but practically unknown on the whole American continent. Storytelling, however, is decidedly native to American Indian culture. It is natural enough then, in view of the Indian's cultural background, that Indian children should rank low in tests built upon knowledge and grasp of proverbs, and high in tests built upon retentiveness of memory as regards stories read or told to them.

So far as language is concerned, our Indian languages and linguistic stocks are totally distinct from all other languages and linguistic stocks of the world. Some recent efforts have been made to prove kinship between some of our Indian languages and the languages of Melanesia and Australia, but the conclusions drawn, while interesting, are very far from convincing, and have not won any appreciable acceptance among specialists in the field. On the whole American continent there are more than one hundred and fifty absolutely distinct linguistic stocks,—stocks quite as distinct one from the other as are our English and other languages of the Indo-European stock from Chinese or Bantu. For instance, the languages spoken by the Iroquoian peoples of New York State are as ut-

terly distinct from the languages that were spoken by the neighboring Algonquian peoples of New England and the Middle Atlantic States as French or Spanish is from Malay. Where and how these hundred and fifty and more absolutely distinct linguistic stocks developed, we can not say. They may have developed under tribal isolation after the arrival of the Indian in America or may have developed in his prehistoric home land in Asia before his migration to the American continent. We may add that Indian languages are just as logically and systematically constructed as are the languages of civilized peoples. Naturally they differ as regards grammar in many important respects from our own Indo-European tongues, but their grammatical processes are worked out just as regularly and just as logically as in our own language. Nor are these languages lacking either in euphony or in abstract terms.

The culture or civilization of the American Indian has in the main, so far as our best evidence goes, developed on the American continent itself. Many of the most characteristic inventions, customs and concepts of the eastern hemisphere are quite absent from aboriginal America. Such, for instance, are the use of the wheel, of domesticated cattle, of proverbs, of alphabetical writing, and of a great number of other traits. On the other hand, the American Indian had much that man in the eastern hemisphere lacked. In agriculture, for example, the American Indian cultivated about forty major plant foods, all or nearly all of which are found in the wild state in America and none of which was found either wild or cultivated in any other part of the world prior to the coming of the white man to the American continent. Maize or corn, white and sweet potatoes, kidney and lima beans, pumpkins and squash, tomatoes and many other plant foods that are staple for us to-day are borrowed from the Indian.

Among the Indians, as among the other major divisions of the human race, great differences prevailed in the level of material culture. In both the far northern and far southern belts of the American continent, culture was relatively very simple, without agriculture or weaving, and commonly without complicated tribal organization or even the chieftaincy. These far northern and far southern belts of the continent are marginal to the great central belt that extended roughly from the Great Lakes in North America to southern Chile and northern Argentina in South America. In fairly sharp contrast to the dominantly hunting and fishing peoples of the marginal belts, nearly all the peoples of the great central belt were fairly sedentary farmers, whose staple foods were chiefly beans, squash, potatoes, manioc, and particularly maize. Still more centrally located, from the northern Mexican highlands, down through Central America along the western coast of South America to what is now northern Chile, there thrived a much more advanced culture that attained a high degree of skill in architecture and carving, quite advanced political and social institutions, and, among the Mayas in particular, a remarkable system of writing and an astonishingly accurate method of time-reckoning.

In this focal area were the beginnings of a civilization of great attainment and of still greater promise before and at the time of the coming of the white man in the sixteenth century. Enormous strides had already been made beyond the simpler levels of primitive American culture. Had the white man not so ruthlessly put an end to this springtime budding of native Indian civiliza-

tion, it is more than probable that, by this time, there would have been a maturing and flowering of civilization on the American continent quite comparable to that attained in the golden periods of the civilizations of Egypt and Mesopotamia and, later, of the northern Mediterranean area.

Whence came the Indian originally? His physical resemblance to the Mongolian race appears to show pretty clearly that the Indian must have come from the Asiatic continent. It is, of course, quite possible that occasional wanderers may have sailed or have been driven by storms across the Pacific or even across the Atlantic to our American shores. But if so, these sporadic migrants seem to have left little or no impression on either the physical constitution or the culture of the aboriginal American population. Our main evidence points toward the conclusion that the bulk of our Indians came over by way of Bering Strait or its neighborhood. It is likely, too, that they came over, not in one great migration, but in smaller bands or driblets through successive centuries. Both our archeological and our ethnological facts seem also to point to the conclusion that these little bands, at their arrival on the continent, were at a relatively primitive level of culture, without domesticated plants or animals, except probably the dog, without pottery, weaving or other of the more advanced industrial arts.

How long ago this migration or these migrations occurred can not be determined with any accuracy. There have been no such migrations to our knowledge since the discovery of the continent by the white man. It has been customary to consider that the Indian is a comparatively recent arrival on the American continent. Some of the more recent archeological finds as well as some of the ethnological and linguistic data are, in the opinion of some anthropologists, throwing a little doubt on this assumption. We have definite archeological and geological proof for the great antiquity of man in Europe, Northern Africa, Eastern Asia and China. But to date we have no scientific proof that man has been on the American continent any vast length of time. An estimate of ten thousand years for man on the American continent would seem to cover with a good margin such scanty facts as we have bearing on this problem of age, but it is not at all impossible that further evidence may oblige us to put his coming to America at a considerably earlier date.

The present speaker is neither a prophet nor the son of a prophet and so is reluctant to suggest even tentatively what the future may hold in store for the Indian. More commonly, where a minority race lives side by side with a majority one under the same cultural and political institutions, the minority race tends to be absorbed into the majority race and so to lose its culture, its language and its physical identity. Whether or not this will actually occur as regards the Indians of the United States, only the future can disclose.

THE LANDSLIDE AT POINT FIRMIN, CALIFORNIA

By Professor WILLIAM J. MILLER

CHAIRMAN OF THE DEPARTMENT OF GEOLOGY, UNIVERSITY OF CALIFORNIA AT LOS ANGELES

Introduction

There are two features of particular interest in regard to the landslide at Point Firmin, California; first, that a considerable body of bed rock on the coast is slowly moving into the sea, and second, that detailed observations have been, and are being made on the rate of the movement. This movement is taking place with sufficient rapidity to afford an exceptional opportunity of actually observing the various stages of a notable alteration of part of a coastline by shifting of bed rock.

The landslide is taking place just east of Point Firmin at the southern end of San Pedro, which is a part of the city of Los Angeles. The movement was first noticed early in January, 1929, and it has continued without interruption ever since.

On May 7, 1929, Dr. F. L. Ransome made a report on the landslide to the city of Los Angeles. On August 28, 1929, Ralph Arnold, M. H. Bissell and the writer, with much more data available, made another report to the city. Several times since our report was made the writer has visited the locality, noting the changes made during the progress of the slide.

General Character and Extent of the Landslide

The slide involves about five acres of bed rock on land, and an apparently much larger, though rather indefinitely known, body of bed rock under the sea, as indicated by Figs. 1 and 2. This whole block of sliding rock, measured from north to south, is probably one half of a mile long. It is one fourth of a

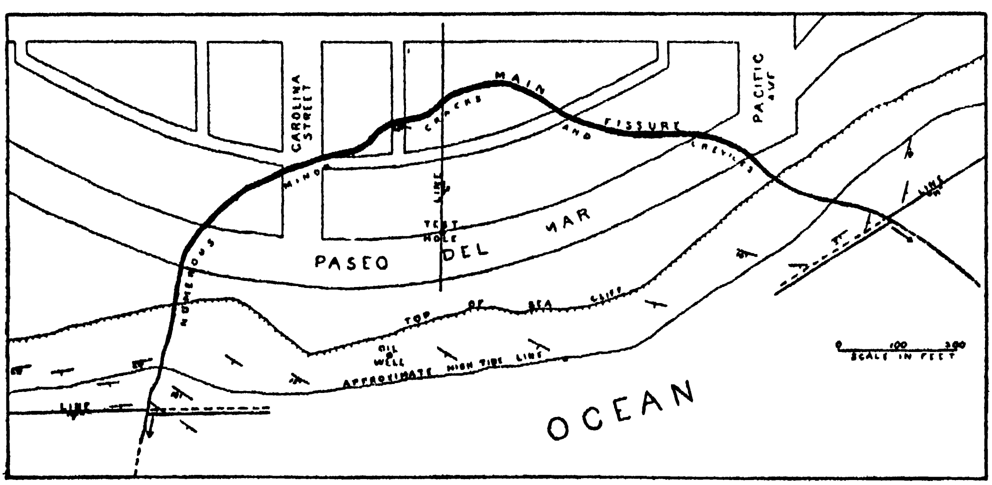


FIG. 1. MAP OF THE LANDWARD PORTION OF THE LANDSLIDE AT POINT FIRMIN, CALIFORNIA.

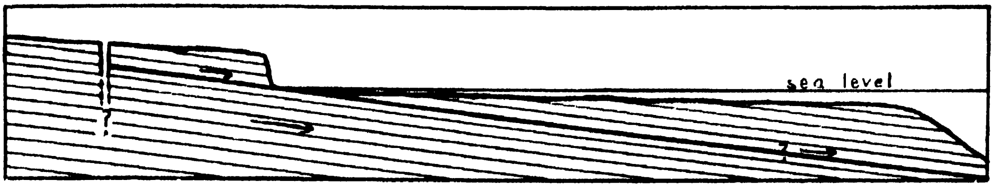


FIG. 2. PROFILE AND STRUCTURE SECTION

OF THE BODY OF SLIDING BED ROCK AT POINT FIRMIN. LENGTH OF SECTION ABOUT ONE HALF OF A MILE

mile wide at the shoreline, and probably much wider out under the sea. This large mass of rock is breaking away from the mainland, leaving in its wake an ever-widening fissure.

The main fissure, which is crescent-shaped (Fig. 1), is plainly exposed for a distance of one third of a mile It is as much as 8 or 10 feet wide at the top Because of slumping of material from the walls, it is impossible to look down into the fissure more than 30 or 40 feet, but it is quite certainly much deeper than that.

During the progress of the slide many secondary cracks and crevices have developed, especially on the inner side of the crescent in the vicinity of the main fissure. There are often small down-faulted and tilted blocks between the crevices. The fissuring and cracking of the ground have caused a number of buildings to be either wrecked or badly damaged, while others have been moved away. Where the ever-widening main fissure crosses streets an attempt is being made to keep it filled with dirt (Fig. 3).

The land area of five acres involved in the slide forms part of the lowest (youngest) of the well-known series of marine terraces of the San Pedro Hills. The top of the soil-covered terrace slopes gently seaward, and it terminates abruptly in a sea cliff about 100 feet high (Fig. 4).

Since the landslide began, a number of small new faults have developed in the sea cliff within the sliding block, mostly within a few hundred feet of the main fracture in the cliff on each side of the block. It is dangerous to walk along the base of the cliff because of falling rocks dislodged by these movements The masonry stairway on the western side has been partly demolished by the faulting and by falling of rock masses

The Rocks and Their Structure

The rocks underlying the block of land involved in the slide are well-bedded shales and sandstones of Tertiary age, overlain by several feet of adobe soil. The strata, excellently exposed in the sea cliff in and near the sliding mass, show a general seaward dip of 10 to 22 degrees, with dips of 10 to 15 degrees prevalent.

Light gray shale greatly predominates in the upper two thirds of the sea cliff, while gray, porous sandstone, from which water oozes, makes up the lower part of the cliff. From the base of the cliff down for hundreds of feet the formation is largely shale as shown by the log of an oil well drilled at the foot of the cliff.

The dips of the strata are indicated on the accompanying map. They clearly prove that the sliding block of land is situated on the flank of a plunging anticline, and that the main fissure on the eastern side of the block at the base of the cliff is close to the axis of the anticline. At the base of the cliff, along the western side of the sliding block, there

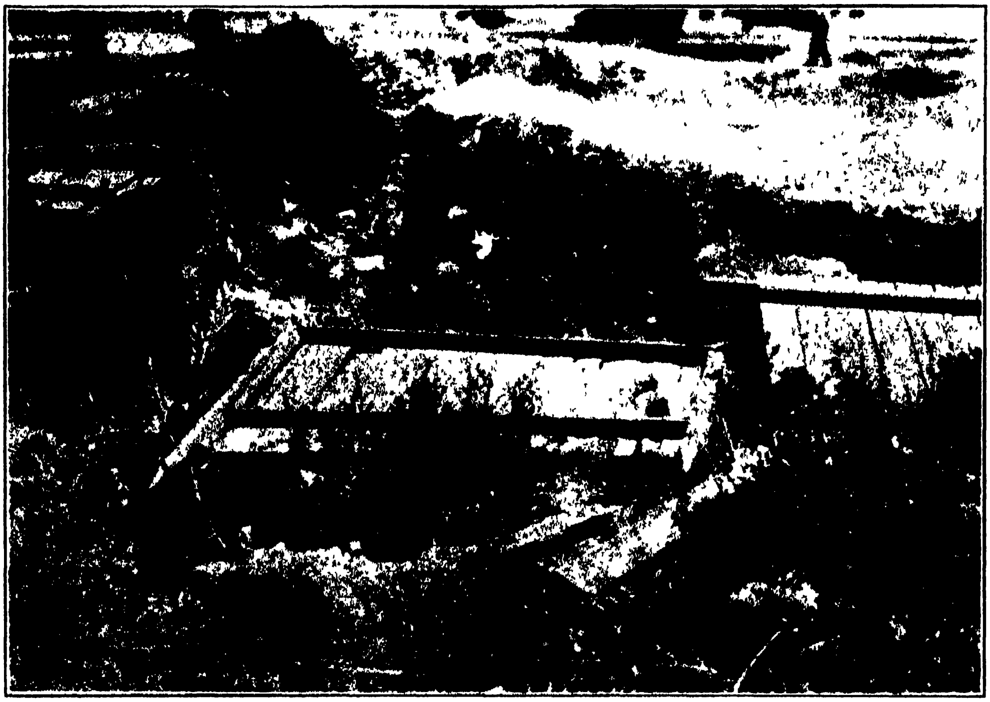


FIG. 3. LOOKING INTO THE MAIN FISSURE NEAR CAROLINA STREET. ARTIFICIAL FILL IN THE DISTANCE (JULY 1, 1930).

is a sharp structural break or dislocation as indicated by the dips.

The rocks and structural features above mentioned extend out under the very shallow sea (maximum depth, 25 feet) for a considerable distance, very likely to the deeper water about 2,000 feet off-shore. The shape and extent of this shallow, as shown on the Coast and Geodetic Survey chart, strongly suggest that the structural lines bounding the eastern and western sliding block of land also bound the shallow, or, in other words, that this shallow is the seaward extension of the landslide.

NATURE AND RATE OF THE MOVEMENT

In the spring of 1929 the city engineer established eight survey lines across various parts of the main fissure or fracture. Three of these are shown on the accompanying map. Since the lines were laid off, weekly observations have been made to determine the character and rate of movement of the landslide.

It has been found that, to June 18, 1930, the middle portion of the sliding block has moved seaward 7.66 feet. This is along line "C" of Fig. 1. During the same time the western portion of the block has moved seaward 8.11 feet as proved by dislocation of line "F," while the eastern part, shown by dislocation of line "H," has moved seaward 6.52 feet. The general outward movement of the whole block has, therefore, been at an average rate of about one tenth of a foot per week. The movement along line "C" has been as low as five hundredths of a foot and as high as five tenths of a foot, no week having failed to show distinct movement on any of the survey lines. Movement along

the other lines has also been somewhat similarly variable.

It is an interesting fact that the slight earthquake of July 8, 1929, was followed by a distinctly accelerated movement of the landslide, the faster movement lasting about two months and reaching a maximum of over five tenths of a foot during the week ending August 21.

The general outward or seaward movement of the block has been accompanied by much less downward movement, ranging from a little less than a foot to about 2½ feet.

There is rather clear evidence that the mass of shale in the upper part of the sea cliff has moved slightly faster than the rocks lower down in the cliff, and Ransome (May 7, 1929) thought it possible that the whole slide might have been thus superficial. Evidence made available since that time, however, renders it certain that the movement is much more deep-seated.

During the summer of 1929 the test hole (Fig. 1) drilled by the city to a depth of 140 feet was found to be sheared off a little above sea-level, while the oil well south of it was sheared off a little below sea-level. This proved the existence of a shear zone or sliding surface within the landslide and at an angle corresponding to the dip of the strata. This sliding surface is indicated in Fig. 2 by the heavy line just under the smaller arrows.

Lines "F" and "H" were laid off on bed rock at the base of the cliff below

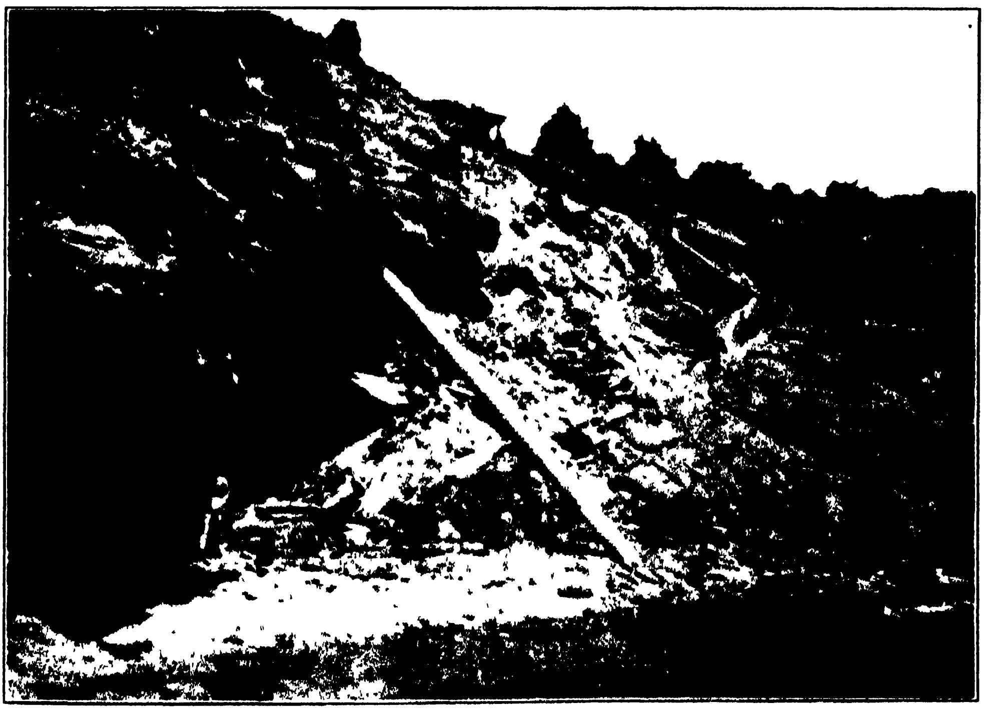


FIG. 4. SCENE WHERE THE MAIN FRACTURE

AND MINOR FAULTS CUT THE SEA CLIFF ON THE WESTERN SIDE OF THE LANDSLIDE. THE LARGE MASS OF RECENTLY FALLEN ROCK DEBRIS HAS PARTIALLY DESTROYED THE MASONRY STAIRWAY (JULY 1, 1930).

FIG. 5 A BLOCK OF LAND
WHICH HAS SUBSIDED ABOUT 8 FEET ADJACENT TO THE MAIN FISSURE 150 FEET WEST OF THE CORNER OF PACIFIC AVENUE AND PASEO DEL MAR (JULY 1, 1930).

high tide level. The dislocation of one of these lines to the extent of 8.11 feet, and the other to the extent of 6.52 feet, with accompanying development of abundant fault breccia and slickensides, shows these movements to be of deep-seated character. The sharp change in strike and dip of the strata along line "F" also supports this idea. It seems impossible, therefore, to avoid the conclusion that the really important sliding surface (or surfaces) is much farther down than the one near sea-level at the base of the cliff.

CAUSE OF THE SLIDE

The fundamental cause of the landslide lies in the character and structure of the rocks. The whole landslide block, including its extensive undersea portion, and consisting very largely of slippery shales on the flank of a distinct anticline with a strong seaward dip, was in such a condition of instability that, under the action of gravity, it finally began to break away from the mainland to move down the dip on one or more rather deep-seated slippery shale zones. Contributing factors may have been the abrupt termination of the landward portion of the slide in a high steep cliff, and of the seaward portion in a less steep slope where the deeper water begins (Fig. 2). Another contributing factor may have been water, used for irrigation in this part of San Pedro, entering certain of the shaly zones.

FUTURE OF THE LANDSLIDE

The movement of the landslide is likely to continue for years, as suggested by the rather remarkably steady sliding

during the past year and a half. As the action proceeds more cracks, fissures and small slumping and tilting blocks are developing within the mass of sliding land. The writer believes it to be likely that the seaward, downward, breaking-up action will continue until the topography of the landslide area will more or less resemble that in the vicinity of Portuguese Point on the coast 5 miles west of Point Firmin. It seems evident that profound landslide action, probably similar to that now in an incipient stage near Point Firmin, broke the land all to pieces, producing a jumbled group of hummocks and depressions, within an area a mile long and half a mile wide in the vicinity of Portuguese Point. The San Pedro Hills quadrangle published by the U. S. Geological Survey plainly shows the disturbed topographic condition near Portuguese Point. This action occurred in very late Quaternary time after the otherwise remarkably preserved lowest (youngest) marine terrace was cut.

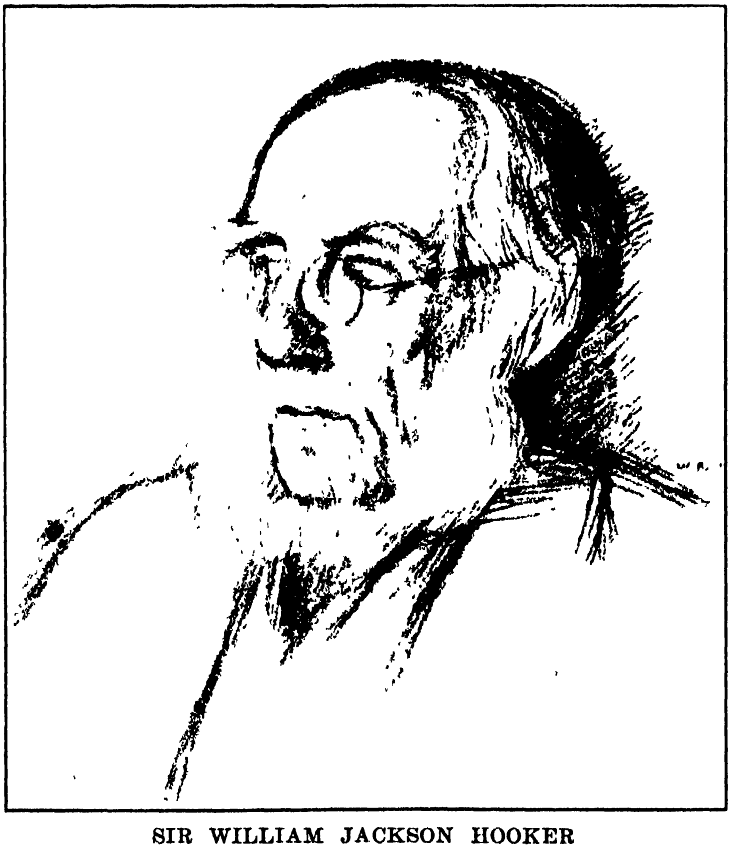
Given a season (or several seasons) of exceptionally heavy rainfall to lubricate the sliding surfaces, and an earthquake of considerable severity to furnish an extra impulse, it is not unreasonable to think that the whole mass of sliding rock near Point Firmin might be set into disastrous motion. It is far more likely, however, that the slower movement will continue for a long time.

THE PROGRESS OF SCIENCE

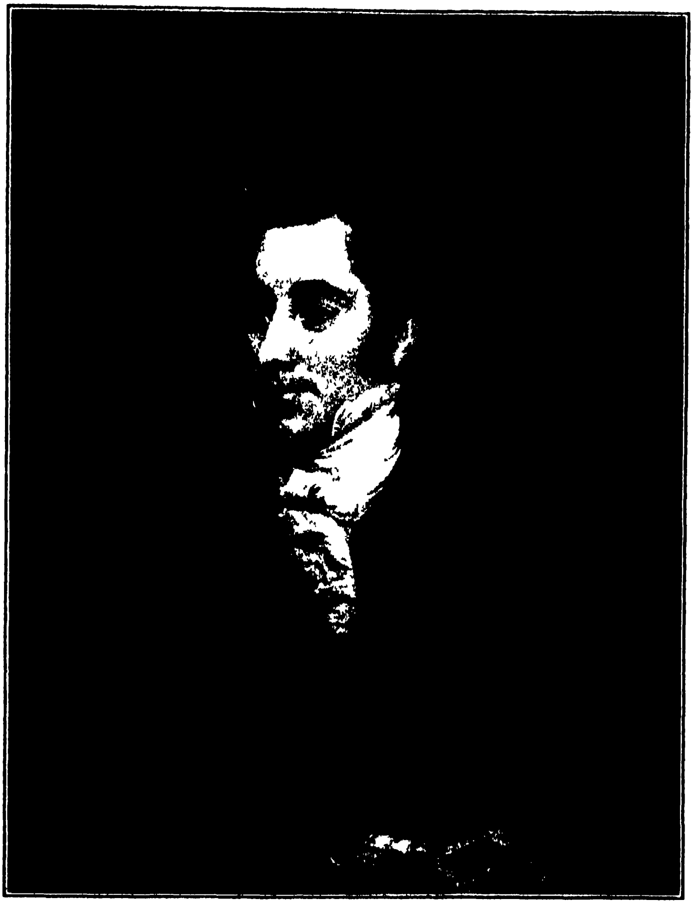
THE HOOKER MEMORIAL AT HALESWORTH

THE unveiling and dedication of a memorial tablet in St. Mary's Church, Halesworth, Suffolk, to the eminent botanists, Sir William and Sir Joseph Hooker, father and son, happily synchronized with the opening of the International Congress of Botanists at Cambridge A large party went over by road to attend the ceremony (Sunday, August 17, 1930), including a generous sprinkling of representative Americans

The association with Halesworth is as follows: William J. Hooker (b. Norwich, 1785) developed a strong leaning towards natural history which acquired a definite botanical direction. Under the advice of his future father-in-law, Dawson Turner, he took over the management of a brewery at Halesworth in 1809, and it was here that his son Sir Joseph was born in 1817. Preoccupied with his botanical interests, it is not surprising that the brewery should have



SIR WILLIAM JACKSON HOOKER

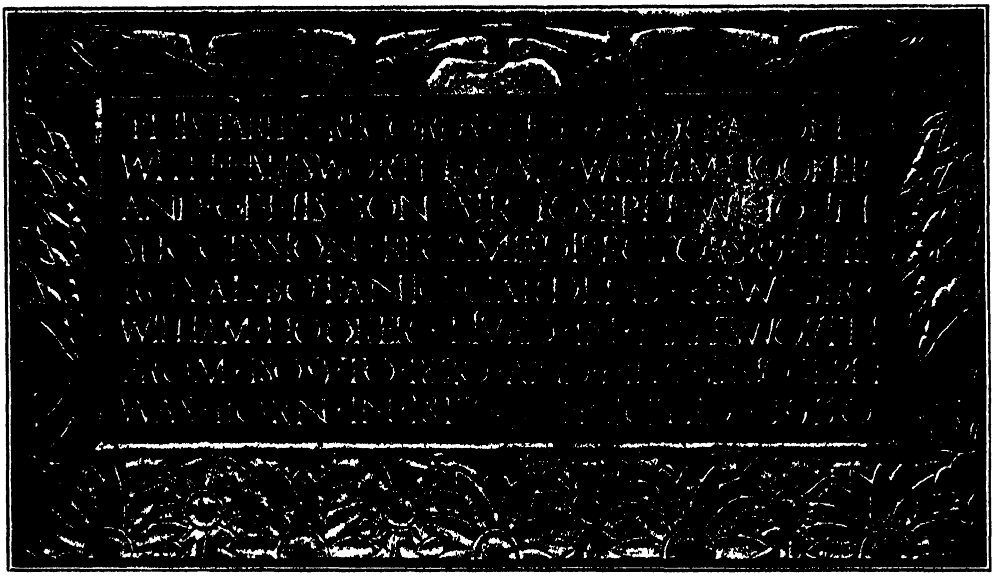


SIR JOSEPH DALTON HOOKER

wilted as a money-making proposition in his hands. The financial stringency, however, was the turning point in his career when, in 1820, he accepted the chair of botany at Glasgow, which Sir Joseph Banks's influence secured for him. Twenty years later (1841) Sir William became the first director of the Royal Botanic Gardens, Kew, and on his death in 1865 he was succeeded by his son Sir Joseph.

Although the ten years' connection of Halesworth with the Hookers had passed out of local memory, all classes of the community welcomed the proposal for a Hooker Memorial and paid due homage to their fellow townsmen of a hundred years ago. The service of dedication (which was fully choral) under the direction of the rector, the Rev. H C. Newbery, was as beautifully rendered as it could have been in any English parish church whatsoever; the actual unveiling was performed by Sir David Prain, ex-director of Kew and successor to the Hookers; and the Bishop of St. Edmundsbury and Ipswich delivered a well-balanced address.

Some 150 botanists and naturalists came from outside, and, with the townspeople, filled the church The Brewery House was thrown open to visitors by



THE MEMORIAL TABLET TO SIR WILLIAM AND SIR JOSEPH HOOKER

WHICH HAS BEEN RECENTLY UNVEILED IN ST. MARY'S CHURCH AT HALESWORTH, SUFFOLK. THE TABLET WAS DEDICATED AT THE TIME OF THE OPENING OF THE FIFTH INTERNATIONAL BOTANICAL CONGRESS IN ENGLAND.

the present owner, Miss Parry, and tea was served to a large gathering at the church rooms. Here Lord Ullswater (formerly Speaker of the House of Commons), a leading resident in the county and chairman of the Hooker Memorial Committee, gave expression to the general appreciation of the local arrangements.

The tablet is the work of the sculptor, McA. H. Gerrard. The inscription is framed in a decorative surround in which the plants employed (it may be explained to prevent controversy in time to come) have no relation to any of the Hookerian discoveries but are used solely as decorative matter.

During the Hooker period, Halesworth was visited by many contemporary botanists, both British and foreign, including Pyrame de Candolle and Lindley. Of Lindley, then a young man, it is recorded that the servants were much concerned because the bed prepared for his use was left unoccupied. On investigation it appeared that Lindley was at the time hoping to be sent abroad to collect plants, and as a measure of preparation for the hardships he expected to endure, he had chosen to sleep on the un-upholstered floor! Providence, however, saw otherwise, and these early hopes were never realized. Lindley became a famous botanist, but rather in the lecture room and herbarium than as a traveler and collector.

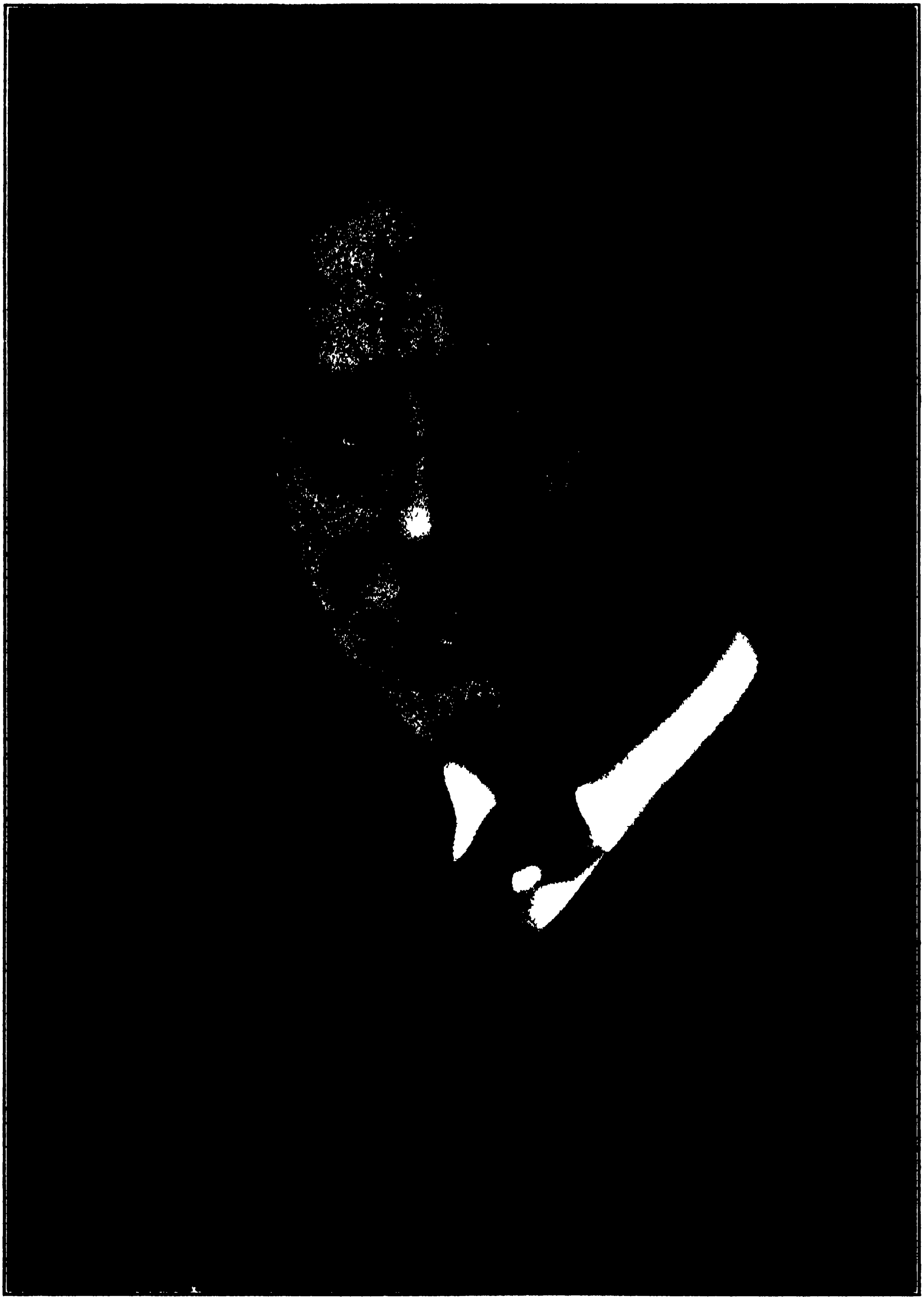
The necessary funds for the tablet were provided by a number of societies and institutions with which the Hookers had been connected, including the court of the University of Glasgow, and also by individuals who had been contemporary with Sir Joseph. Two invitations to contribute were sent abroad and both met with generous response. One was from the present Madame de Candolle, of Geneva, as representing the family

which had such close relations with the Hookers; the other, jointly, from the trustees of the Asa Gray Herbarium and the New York Botanical Garden. The link here was Asa Gray, a frequent guest at Kew, and Sir Joseph Hooker's host and traveling companion when he visited the United States.

Of the Hookers themselves, Sir William was the founder of Kew Gardens and the Kew establishment in its modern form, and Sir Joseph continued his work. As botanist, Sir William's work dealt more particularly with ferns and bryophytes, and the number of publications from his hand is amazing (*cf* "Annals of Botany," 1903) Sir Joseph was, no doubt, the more eminent, and rose to the presidency of the Royal Society. His work lay especially in the field of geographical botany and the taxonomy of flowering plants He was author of the "Flora of British India," and wrote, in conjunction with Bentham, the "*Genera plantarum.*" Though he retired from Kew in 1885, he remained active in the subject till his death in 1911. Of the many distinctions that came to him, the Order of Merit was the one he esteemed most highly. Sir Joseph was married twice, first to the daughter of Professor J S. Henslow, the inspirer of Darwin, and later to the widow of Sir William Jardine. Both families were represented at the ceremony in the persons of the half-brothers, Reginald Hooker and Richard Hooker A daughter of Sir Joseph (still living) became the wife of the late Sir William Thiselton-Dyer, who succeeded his father-in-law in the directorship of Kew, and did so much for the botanical and economic progress of British overseas possessions and dominions.

F W. OLIVER
QUAIN PROFESSOR OF BOTANY,
UNIVERSITY OF LONDON

THE BREWERY HOUSE AT HALESWORTH
THE BIRTHPLACE OF SIR JOSEPH HOOKER



DR. PHOEBUS A. LEVENE

MEMBER OF THE ROCKEFELLER INSTITUTE FOR MEDICAL RESEARCH, WHO HAS BEEN AWARDED THE WILLARD GIBBS MEDAL "AS THE OUTSTANDING AMERICAN WORKER IN THE APPLICATION OF ORGANIC CHEMISTRY TO BIOLCGICAL PROBLEMS."

THE RHENIUM ATOM

SIXTY years have passed since the Russian chemist, Dmitri Mendeléev, proposed the periodic law of chemical elements, which stated that "the elements arranged according to the magnitude of atomic weights show a periodic change of properties" Mendeléev recognized chemical valency as the outstanding periodic property of the elements, and when he ordered the known elements in similar groups or periods he found it necessary to insert a number of blank spaces, which corresponded to undiscovered chemical elements His faith in the periodic law as a fundamental law of nature was so strong that he predicted the existence and properties of six new elements. All these have since been found, they are now known as scandium, gallium, germanium, polonium, masurium and rhenium The first three were discovered within fifteen years after their prediction, but the last two were found only a few years ago Of course the last two are at present of the greatest scientific interest because they are the latest additions to the chemical family and there is still much to learn about them Their eventual discovery after more than half a century of search marks one of the greatest triumphs of methodical science over elusive nature

When Mendeléev first proposed the periodic law he saw that the chemical elements homologous to manganese were missing in the two succeeding periods or groups, and he called these "eka-manganese" and "dvi-manganese" Within the past twenty years it has been established that atomic number, that is, the number of electrons in an atom, is a more fundamental property than atomic weight and each chemical atom is thus described by a number. The list begins with hydrogen 1, ends with uranium 92; and in this system manganese is number 25, eka-manganese is number 43, and dvi-manganese is number 75. Discovery of both 43 and 75 was announced in 1925 by two German chemists, Walter Noddack and Ida Tacke, and they proposed the names "masurium" and "rhenium" Perhaps the main reason for not detecting these elements before is to be found in their extreme rarity. It is an odd fact that in the earth's crust the elements with odd atomic number are usually only one tenth to one twentieth as plentiful as the next succeeding element with even atomic number, and it is to be noticed that both 43 and 75 are odd. It is estimated that these elements constitute about one part in a billion of the earth's crust.

The first proof of the capture of the new elements was evidence of 3 or 4 new lines in x-ray spectra, but the interpretation of this evidence was questioned by critics and it is probable that even now many people not familiar with such proofs may be skeptical as to the real existence of the new elements. All doubts concerning the reality of rhenium 75 are now swept aside by the recent investigations of Dr. W F Meggers, of the Bureau of Standards, who has described the optical emission spectra of this new element. As is well known, each type of chemical atom when properly excited emits light which, when dispersed into a spectrum, is seen to consist of bright lines, the number, relative intensity and distribution of the lines being uniquely characteristic of the atom. These spectra usually consist of hundreds or in some cases thousands of lines, but the methods of observing are so powerful and sensitive that no line of any element is strictly identical with any line of any other element and can not be mistaken or misidentified. The emission spectra of rhenium have now been photographed and measured throughout the entire visible spectrum and in the ultra-violet and infra red; they are found to consist

Wide World

DR. WILLIAM F. MEGGERS

STANDING BESIDE A CONCAVE GRATING SPECTROGRAPH WITH WHICH THE EMISSION SPECTRUM OF RHENIUM WAS PHOTOGRAPHED. HE IS HOLDING A VIAL CONTAINING HALF A GRAM OF PURE PERRHENATE.

of some 2,000 lines, all of which are new to the science of spectroscopy, they are not identifiable with lines emitted by any other known atoms, and are therefore regarded as characteristic of rhenium

Among the strongest spectrum lines there are several which are extremely important for detecting the presence of rhenium in certain minerals Experiments show that spectral lines characteristic of rhenium atoms are visible in the light of an electric arc when the ratio of rhenium to other atoms present is one to a million[1] This test is about a thousand times more sensitive than the x-ray spectrum or any chemical test

Since spectral lines are considered to represent changes in atomic energy it follows that the structure of a spectrum is intimately connected with the structure of an atom; indeed, the laws of spectral structure have been definitely correlated with electron configuration in the past few years so that it is now possible to describe the outer structure of an atom by analyzing its spectrum Analysis of the spectrum of neutral rhenium atoms shows that the atoms have 7 outer (valence) electrons, just like manganese[1]

Another interesting feature of the rhenium spectra is seen in the complex character of certain lines, many of them are relatively wide and under high magnification are found to consist of two to six components This hyperfine structure of spectral lines is not accounted for by the electron configurations provided by the theory of spectra but is believed to be due most generally to the interaction of the nucleus of an atom with its surrounding electrons It is a significant fact that practically all the atoms with odd atomic number show this phenomenon This phase of the rhenium spectra will be pursued further because it offers an opportunity to develop the theory of hyperfine structure and will thus disclose still more of the secrets of rhenium atoms

THE APPLICATION OF QUANTUM MECHANICS TO PAST EVENTS

WE have the privilege of printing a communication from the California Institute of Technology which was included in the mid-March number of *Physical Review* It is signed by Drs Albert Einstein, Richard C. Tolman and Boris Podolsky. This contribution is of general interest because it shows that the principles of quantum mechanics involve an uncertainty in the description of past events and that they can be applied to macroscopic phenomena such as the opening and closing of a shutter.

It is well known that the principles of quantum mechanics limit the possibilities of exact prediction as to the future path of a particle. It has sometimes been supposed, nevertheless, that the quantum mechanics would permit an exact description of the past path of a particle

The purpose of the present note is to discuss a simple ideal experiment which shows that the possibility of describing the past path of one particle would lead to predictions as to the future behavior of a second particle of a kind not allowed in the quantum mechanics It will hence be concluded that the principles of quantum mechanics actually involve an uncertainty in the description of past events which is analogous to the uncertainty in the prediction of future events And it will be shown for the case in hand that this uncertainty in the description of the past arises from a limitation of the knowledge that can be obtained by measurement of momentum.

Consider a small box B, as shown in the figure, containing a number of identical particles in thermal agitation, and provided with two small openings which are closed by the shutter S. The shutter is arranged to open automatically for a short time and then close

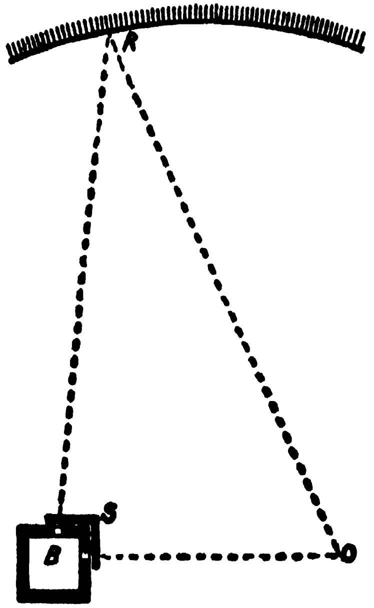


DIAGRAM OF THE IDEAL EXPERIMENT.

THE BOX, B, WOULD CONTAIN A NUMBER OF IDENTICAL PARTICLES IN THERMAL AGITATION. THE OPENING OF THE SHUTTER, S, WOULD PERMIT PARTICLES TO REACH THE OBSERVER, O, BY TWO PATHS: DIRECTLY AND BY THE WAY OF THE REFLECTOR, R.

again, and the number of particles in the box is so chosen that cases arise in which one particle leaves the box and travels over the direct path SO to an observer at O, and a second particle travels over the longer path SRO through elastic reflection at the ellipsoidal reflector R.

The box is accurately weighed before and after the shutter has opened in order to determine the total energy of the particles which have left, and the observer at O is provided with means for observing the arrival of particles, a clock for measuring their time of arrival and some apparatus for measuring momentum. Furthermore, the distances SO and SRO are accurately measured beforehand—the distance SO being sufficient so that the rate of the clock at O is not disturbed by the gravitational effects involved in weighing the box, and the distance SRO being very long in order to permit an accurate reweighing of the box before the arrival of the second particle.

Let us now suppose that the observer at O measures the momentum of the first particle as it approaches along the path SO, and then measures its time of arrival. Of course the latter observation, made for example with the help of gamma ray illumination, will change the momentum in an unknown manner. Nevertheless, knowing the momentum of the particle in the past, and hence also its past velocity and energy, it would seem possible to calculate the time when the shutter must have been open from the known time of arrival of the first particle, and to calculate the energy and velocity of the second particle from the known loss in the energy content of the box when the shutter opened. It would then seem possible to predict beforehand both the energy and the time of arrival of the second particle, a paradoxical result, since energy and time are quantities which do not commute in quantum mechanics.

The explanation of the apparent paradox must lie in the circumstance that the past motion of the first particle can not be accurately determined, as was assumed. Indeed, we are forced to conclude that there can be no method for measuring the momentum of a particle without changing its value. For example, an analysis of the method of observing the Doppler effect in the reflected infra red light from an approaching particle shows that, although it permits a determination of the momentum of the particle both before and after collision with the light quantum used, it leaves an uncertainty as to the time at which the collision with the quantum takes place. Thus in our example, although the velocity of the first particles could be determined both before and after interaction with the infra red light, it would not be possible to determine the exact position along the path SO at which the change in velocity occurred, as would be necessary to obtain the exact time at which the shutter was open.

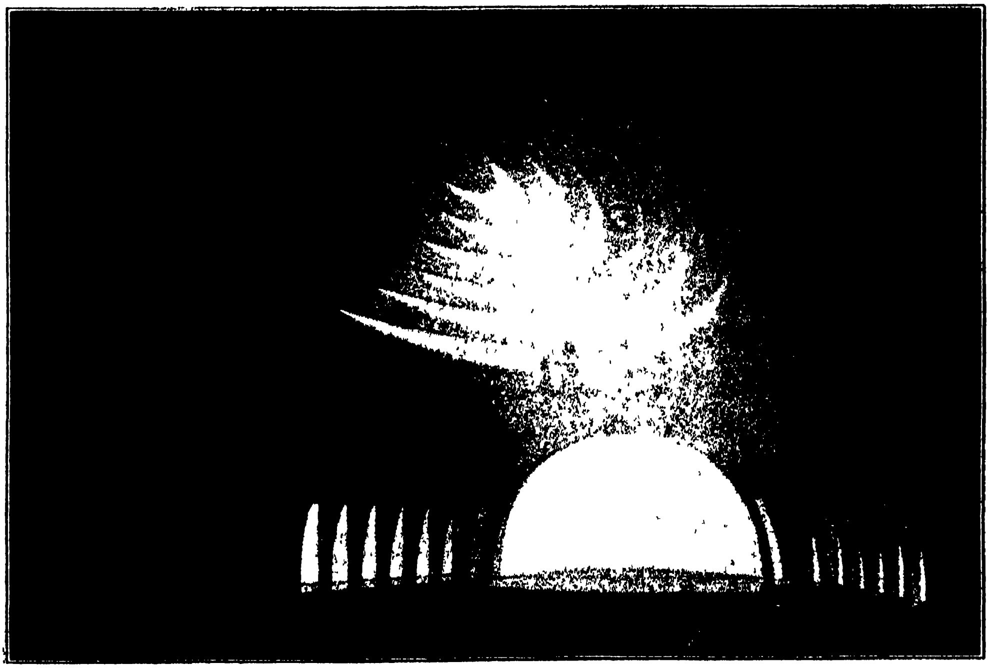
It is hence to be concluded that the principles of the quantum mechanics must involve an uncertainty in the description of past events which is analogous to the uncertainty in the prediction of future events. It is also to be noted that although it is possible to measure the momentum of a particle and follow this with a measurement of position, this will not give sufficient information for a complete reconstruction of its past path, since it has been shown that there can be no method for measuring the momentum of a particle without changing its value. Finally, it is of special interest to emphasize the remarkable conclusion that the principles of quantum mechanics would actually impose limitations on the localization in time of a macroscopic phenomenon such as the opening and closing of a shutter.

THE NEW SCHOOL FOR SOCIAL RESEARCH

The New School for Social Research is now occupying its new building on West 12th Street in New York City It represents an investment of $1,000,000 00 and affords accommodations for 2,000 students

The New School is an institution of "education for the educated." It has neither teachers nor classes in the conventional academic sense No "credits" are earned by taking its courses; no degrees are given. Leaders of thought in the social and political sciences, psychology and the arts teach by lectures or discussions. Those who sit under them are men and women whose college and university days are well behind them and who have come to days of their own especial intellectual needs and inclinations In a very real sense the students themselves determine the curriculum, and specific provision is made for groups that wish to cooperate in inquiry and research of their own selection.

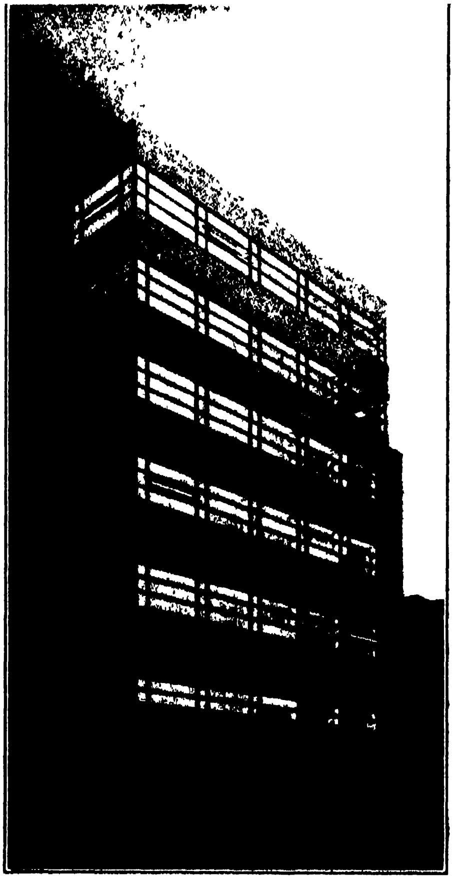
In the eleven years that the school has been in existence it has enrolled more than 10,000 persons. No small number have been on the rosters without interruption from the beginning Every field of intellectual activity and most of the countries of the world have been represented among the instructors and lecturers -such names appear as Harry Elmer Barnes, B M. Baruch, Charles A Beard, Franz Boas, H. N Brailsford, Aaron Copland, John Dewey, H. W L Dana, George A Dorsey, Waldo Frank, David Friday, Francis Hackett, Joseph Jastrow, Horace M Kallen, Joseph Wood Krutch, Alfred Kreymborg, Everett Dean Martin, Harry A. Overstreet, Ralph M Pearson, Roscoe Pound, Morton Prince, James Harvey Robinson, Gaetano Salvemini, Gilbert Seldes and Edwin R A Seligman



THE AUDITORIUM

WHICH IS BELIEVED TO BE THE ONLY OVAL SHAPED ROOM OF ITS KIND IN THE WORLD.

The scheme of the new building was created by Dr. Alvin Saunders Johnson, who has been director of the New School for the past seven years Joseph Urban was the architect, and the structure is among the most notable of his achievements. Some of the things he has done are pure innovations architecturally—the auditorium, for example. It is oval in form—the first of its kind. A domical ceiling makes it oval in cross section as well as in ground plan, it is without pillar on the floor or offset in the walls, so that neither sight nor sound is broken from any point All the light comes from the ceiling, five semicircles of 100-watt lamps, 177 altogether, flooding their radiance toward the stage. An unusual use is made of "side" stages extending out from the proscenium and opening onto the main floor through seven arches. From fly galleries it is possible to give any desired effect of color or intensity. The auditorium has been wired for sound after a plan worked out by Professor Floyd Rowe Watson, of the University of Illinois, and T. F. Bludworth, of New York, so that volume may be controlled absolutely and all echoes and reverberations absorbed.



THE NEW SCHOOL FOR SOCIAL RESEARCH

The façade of the building is distinguished by windows sweeping the full width and by alternating white and black brickwork The basement contains an auditorium with a sunken floor where the dance will be taught as one of the arts. On the mezzanine floor above the auditorium there is a group of "talk-over niches." There are six classrooms on the second floor with a seating capacity of 750, and with the largest of them wired for sound. The third floor is given over to offices and an exhibition room, and on the fourth floor the principal space is occupied by the library, with stacks for 15,000 volumes and—a most important adjunct—a bibliographical guide to the social and political science resources of all the other libraries of the city. On the fifth floor are kitchen and pantry facilities, dining-rooms and an exhibition hall. On the sixth floor there is an apartment for Daniel Cranford Smith, treasurer of the school, from whom the site was purchased and who is to have a life tenancy of this floor.

The penthouse encloses a studio whose north wall is a single window There is a terrace outside which may be used as a work-room, and on the south side are two smaller terraces similarly available. Not only are the graphic and plastic arts taught here but students may work "on their own."

THE SCIENTIFIC MONTHLY

JUNE, 1931

THE NEW BERMUDA BIOLOGICAL STATION FOR RESEARCH

(INCORPORATED 1926)

By Professor EDWIN G. CONKLIN

PRESIDENT OF THE BOARD OF TRUSTEES OF THE STATION
DEPARTMENT OF ZOOLOGY, PRINCETON UNIVERSITY

THE peculiar advantages of Bermuda for biological and oceanographic studies have been made known by numerous investigators and by several scientific expeditions. In 1859 J Matthew Jones, Esq, F L S., barrister of the Middle Temple, published a book of 200 pages entitled "The Naturalist in Bermuda," which Charles Darwin in his "Origin of Species" called an "admirable account" In 1876 Mr. Jones published a "Visitor's Guide to Bermuda," containing a list of the more common plants and animals, and in 1884 he and G Brown Goode, with the collaboration of five other specialists, published in the Bulletin of the U. S. National Museum an extensive work on "The Natural History of the Bermudas"—their geology, physiography, botany and zoology The famous *Challenger* Expedition visited Bermuda in 1873 and made a special study of the ocean depths surrounding the islands; various volumes of the reports of that expedition contain matter relative to the geology, meteorology, botany and marine zoology of Bermuda. Angelo Heilprin in 1889 published a valuable volume on the natural history of "The Bermuda Islands." Alexander Agassiz visited Bermuda in 1894 and studied particularly the ocean depths and slopes around the islands, the sounds, lagoons and coral reefs with especial reference to the method of formation of coral islands. In 1902 and 1907 Addison E Verrill published in the Transactions of the Connecticut Academy of Arts and Sciences two volumes on "The Bermuda Islands; Their Scenery, Climate, Physiography, Natural History, Paleontology and Coral Reefs, with Sketches of Their Early History and the Changes Due to Man." Most recent of all, and in some respects most distinctive, are the expeditions of the New York Zoological Society under the directorship of William Beebe during the years 1929 to 1931; this expedition is devoting particular attention to the deep sea fauna, and actual descents have been made to depths far greater than have ever before been reached by man.

These are but a few of the many scientific studies relating to Bermuda, all of which indicate the wealth of opportunity which these islands afford for research work in the natural sciences.

(1) THE ORIGINAL BERMUDA BIOLOGICAL STATION FOR RESEARCH

The idea of creating in Bermuda a laboratory for biological studies in con-

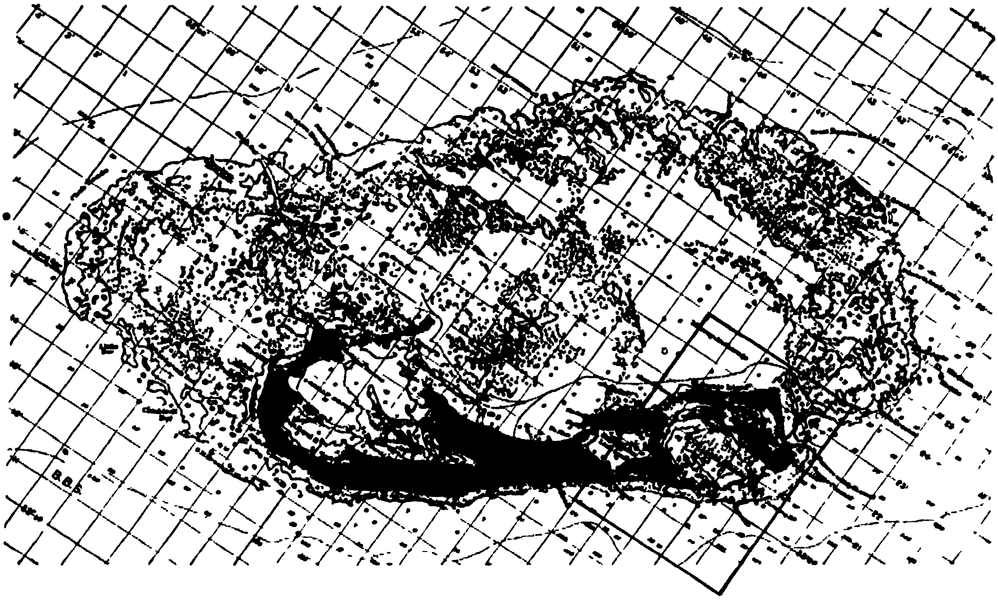


CHART OF BERMUDA ISLANDS

nection with a public aquarium was suggested as early as 1896, and later the Bermuda Natural History Society was organized with the purpose of furthering such an undertaking. Half a dozen years, however, elapsed before definite results were attained. In 1903 Harvard University and New York University entered into an agreement for the establishment and joint support of the Bermuda Biological Station for Research, with Professor Edward L. Mark as director and Professor Charles L. Bristol as associate director, it being understood that the station was ultimately to be associated with the public aquarium which the colony contemplated establishing. After a careful study of the needs of the aquarium as well as the opportunities for carrying on scientific investigations, the Flatts at the Inlet to Harrington Sound was selected as the location of the station. Provision was made for laboratory facilities as well as for the board and lodging of investigators at the Hotel Frascati, and a printed circular was issued inviting zoologists and botanists

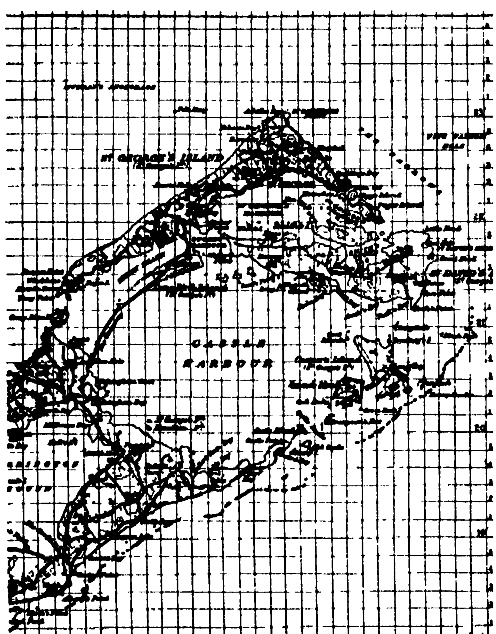


CHART OF N. E. RECTANGLE

SHOWN IN HEAVY OUTLINES IN CHART OF BERMUDA ISLANDS, SHORE HILLS AREA, CROSS-HATCHED.

to share in the opportunities of the station without the payment of any laboratory fees. There were in attendance at this first session of the station—June 22 to August 22, 1903—between thirty and forty workers. The summer session was repeated under the same conditions in 1904 and 1905. In 1906 the colony purchased at the Flatts a plot of land for the erection of the aquarium and station, but owing to straitened circumstances was unable to carry out the rest of the plan. Within a year, however, the Natural History Society leased from the War Department Agar's Island and converted its "magazine" into a public aquarium Meanwhile the agreement between New York and Harvard Universities had been abrogated, and the society invited Professor Mark, as the representative of Harvard University, to take over the management of the station at Agar's Island. The station has been in continuous existence there since 1907, the opportunity for work at other times than the regular summer sessions having been provided for as occasion arose. For nearly three years (1915–1918) Dr. William J. Crozier was resident naturalist at the station, and Mrs. Crozier was librarian and recorder About 280 scientists have carried on studies at the station, and the printed publications of their researches now amount to upwards of 160 papers arranged in seven volumes.

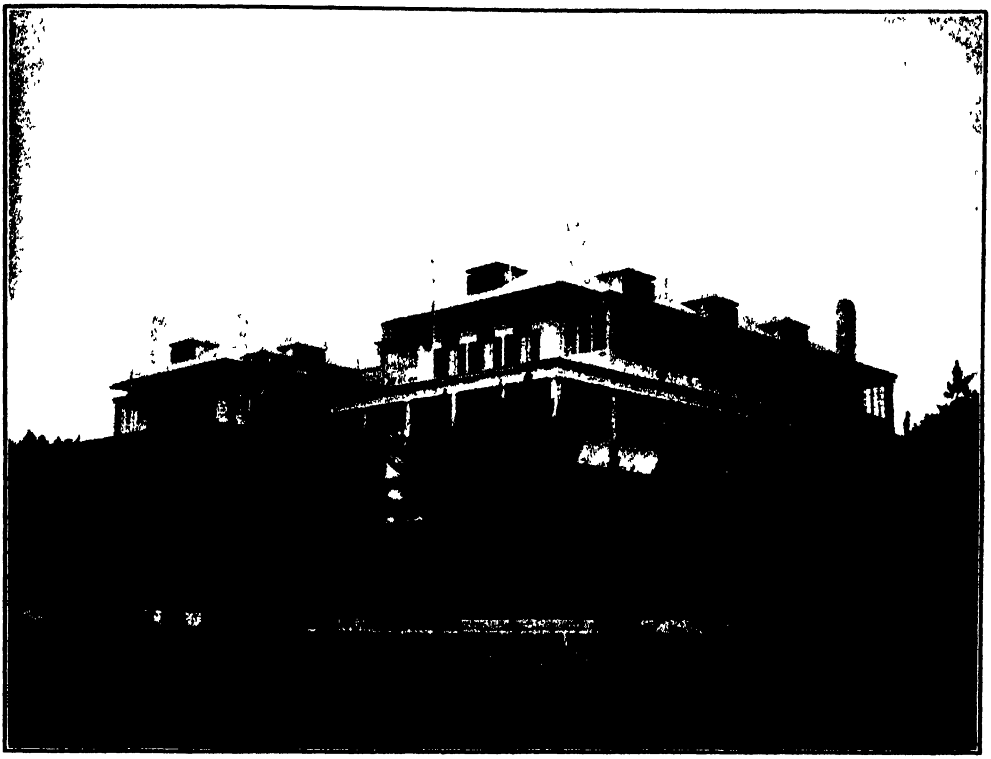
From the spring of 1917 to 1919 Agar's Island was requisitioned for military purposes, and the whole equipment of the station was transferred for that period to Dyer's Island, a short distance away. After the World War the aquarium at Agar's Island was discontinued, and the island was leased from the War Department by Harvard University for the exclusive use of the station, which was continued there until the opening of the reorganized station at Shore Hills. In the meantime a splendid public aquarium was established on the site originally selected at the Flatts, but leaving no suitable space for an enlarged biological and oceanographic station, such as was contemplated in the plan of reorganization.

(2) The Reorganized Bermuda Biological Station for Research, Inc.

In August, 1925, twelve persons who had worked at the Bermuda Station, including Dr. E. L. Mark, its director, met in Woods Hole, Massachusetts, and formulated a letter which was sent to many biologists in Great Britain, Canada and the United States asking for their cooperation in forming a corporation to make the station more widely useful as an international laboratory, and requesting the nomination of five persons to serve as a committee on reorganization. Letters of cordial endorsement of the project were received from the Royal Society of London, the Royal Society of Edinburgh, the Royal Society of Canada, the Biological Board of Canada, the Honorary Advisory Council for Research (Canada), the National Research Council, of the United States, and from many other scientific institutions and persons. One hundred and thirty-four persons (later increased to 180) joined the corporation and the following committee on reorganization was elected: C L. Bristol, E. G. Conklin (chairman), E. V. Cowdry (secretary), E. L Mark and H W. Rand. The committee drew up articles of incorporation and by-laws and nominated sixteen members of the corporation to be trustees, the twelve receiving the highest number of votes to be declared elected. By the votes of more than 150 members of the corporation twelve trustees were elected, eight of them residents of the United States, two of Great Britain, and one each of Bermuda and Canada. On June 28, 1926, the Bermuda Bio-

SHORE HILLS SEEN FROM SOUTH ACROSS FERRY REACH

ENGINE HOUSE ON RIGHT; COTTAGES AND BATHING PAVILION ON LEFT.

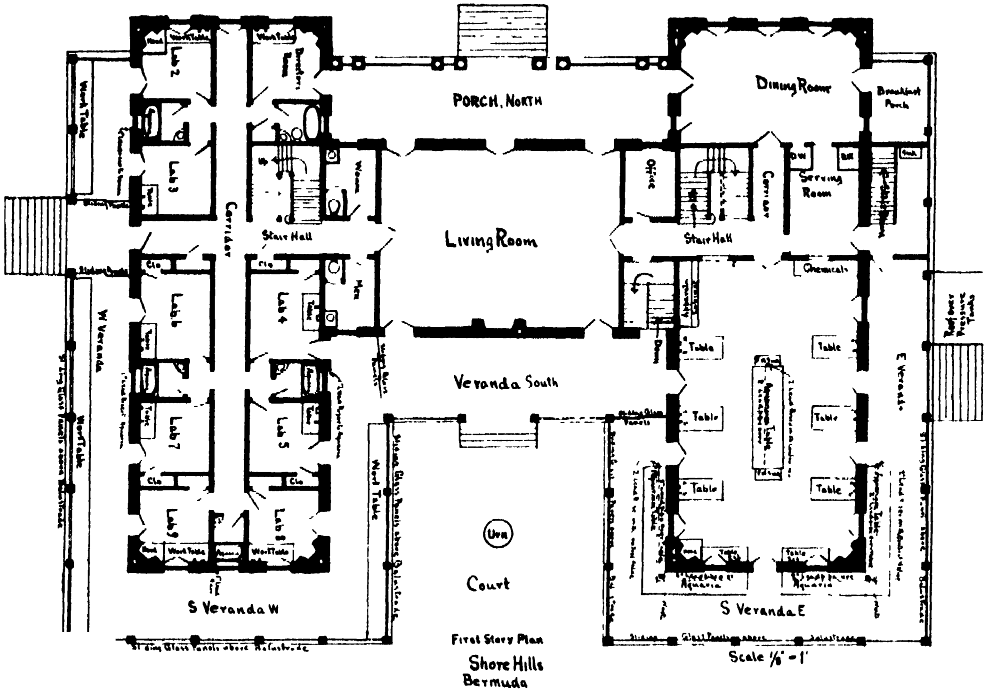


SHORE HILLS FROM SOUTHEAST
SHOWING VERANDAS AND SLEEPING PORCHES.

logical Station for Research was incorporated under the laws of the State of New York.

On April 23, 1930, a special meeting of the corporation and trustees was held in New York for the purpose of amending the articles of incorporation so as to permit the enlargement of the board of trustees to twenty-four persons, and on April 26 the amended charter was approved by the proper authorities of the State of New York. At the annual meeting, January 3, 1931, eight additional members were elected to the board of trustees, which now consists of twenty persons, thirteen from the United States, three from Bermuda, and two each from Great Britain and Canada.

Special meetings of the trustees were held in August and October, 1926, and the first annual meeting of the corporation and trustees was held in New York on December 27, 1926. At that meeting officers were elected, an executive committee appointed, and a report received from a committee of four trustees that had visited Bermuda to select a site for a permanent station. After this committee had inspected more than twenty proposed sites they reported in favor of a tract of 12 acres in St. George's Parish, fronting on Ferry Reach and Mullet Bay, and known as "The Hunter Tract," which could be purchased for £5,500. This site was approved by the trustees and corporation, and later a petition was addressed to the governor and legislature of Bermuda asking (1) that the Bermuda Biological Station for Research, Inc., be granted the privilege of holding real estate in the Islands of Bermuda; (2) that when the trustees should satisfy the governor-in-council

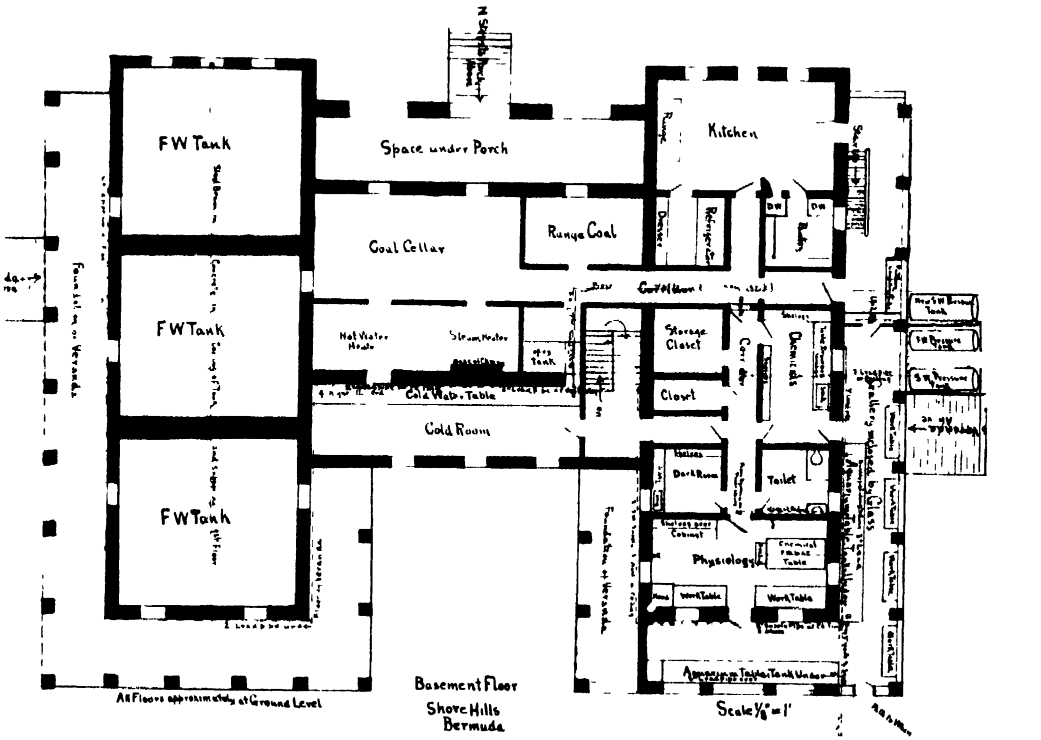


FIRST FLOOR PLANS

SHOWING ARRANGEMENT OF LABORATORY ROOMS, AQUARIA, LIVING ROOMS, ETC.

that not less than £50,000 endowment had been raised, the Colonial Government should purchase and transfer to the trustees the Hunter property; (3) that all supplies and equipment imported for the purposes of the station be exempted from customs duties; (4) that an annual grant of £200 a year for a period of ten years be made by the Bermuda Government for the support of the station. On June 24, 1927, the legislature of Bermuda passed the "Biological Station Act of 1927," enacting each and all of these articles.

With this friendly and generous action on the part of the Government of Bermuda, the trustees applied to the General Education Board of the Rockefeller Foundation for a grant to meet the conditional gift by the Government of Bermuda and to provide for the development and maintenance of the station. In the meantime the National Academy of Sciences of the United States had appointed a committee on oceanography which, with the aid of a grant from the Rockefeller Foundation, undertook the preparation of an extensive report on the needs and opportunities of this branch of science; the Foundation therefore postponed action on the application of the Bermuda trustees until this could be considered in connection with the report of the committee on oceanography. This report of 165 typewritten pages recommended that an oceanographic institution be established in a central location on the Atlantic Coast and that this "be supplemented by two branch stations, one sub-arctic and the other truly oceanic in location. The latter location would be served admirably by the Bermuda Biological Station for Research, Inc., which has the support of the committee in its efforts to complete its organization." This report was approved by the National Academy of Sciences in



BASEMENT FLOOR PLAN

SHOWING ARRANGEMENT OF LABORATORY ROOMS, AQUARIA, ETC.

November, 1929, and on November 13 of that year the Rockefeller Foundation appropriated £50,000 to meet the condition imposed by the Bermuda Legislature; on March 29, 1930, the Hunter Tract was purchased by the Government of Bermuda and conveyed to the trustees, and on April 4, 1930, the Rockefeller Foundation paid to the Bermuda Biological Station for Research, Inc., £50,000.

A committee of the trustees visited Bermuda in February, 1930, employed a local architect and began preparation of plans for a new laboratory, boathouse, wharves, and the remodeling of the old residence on the Hunter Tract In July and August, 1930, the president and treasurer were in Bermuda with the intention of letting contracts for the buildings, but the plans were not in final form and little progress was made.

(3) THE NEW STATION AT "SHORE HILLS," ST. GEORGE'S, BERMUDA

At that time a large sanitarium-hotel property known as "Shore Hills," almost adjoining the Hunter Tract, was offered for sale at a very low price and some of the leading citizens of Bermuda suggested that the trustees reconvey to the government the Hunter Tract on condition that the government appropriate £5,500 toward the purchase of "Shore Hills" This proposal was approved by the trustees, the Rockefeller Foundation, and finally by the Government of Bermuda, and on March 26, 1931, the trustees took possession of "Shore Hills," one of the finest properties in St. George's Parish, consisting of more than 14 acres of land fronting on Ferry Reach, with a main building of stone and concrete, which will be used as laboratory and residence, to-

SOUTHEAST VERANDA

LOOKING TOWARD SWING BRIDGE OVER FERRY REACH; ST. GEORGE'S HARBOR IN THE DISTANCE.

gether with five cottages, boat and bathing houses, engine house, wharves, etc., all completely furnished and for a price less than the estimated cost of the new laboratory alone. It is fitting in this connection to call particular attention to the generous action of the Government of Bermuda in thus doubling for the present its outlay for the station, in view of the fact that the Hunter Tract may not be immediately disposed of to advantage. All friends of the station are under increased obligation to the government and people of Bermuda for this further evidence of their interest and support.

The buildings at Shore Hills are now being repaired and remodeled for the uses of the station, and it is expected that they will be ready for occupancy about June 15, 1931. There will be in the basement of the main building a physiological laboratory, with accommodations for five or six workers, an aquarium room, a dark room, a cold room and a chemical store room, as well as kitchen, laundry and other rooms for household purposes. On the first floor there will be a large general laboratory, with accommodations for eight or more investigators, and nine private laboratories, all of them supplied with aquaria and running salt water, as well as with gas and electricity; there are also on this floor a living room, a dining room and serving room as well as extensive verandas. The library will be located on the second floor, and in addition there are on that floor eighteen bedrooms, each with an outdoor sleeping porch, and twelve baths. The cottages will afford accommodations for employees and those investigators with families who prefer to live outside

the main building. There are tennis courts and a portion of a golf course on the grounds, a bathing pavilion and an excellent bathing beach. On the whole, no more delightful place for residence and for scientific work can be found in the sub-tropics of the western Atlantic.

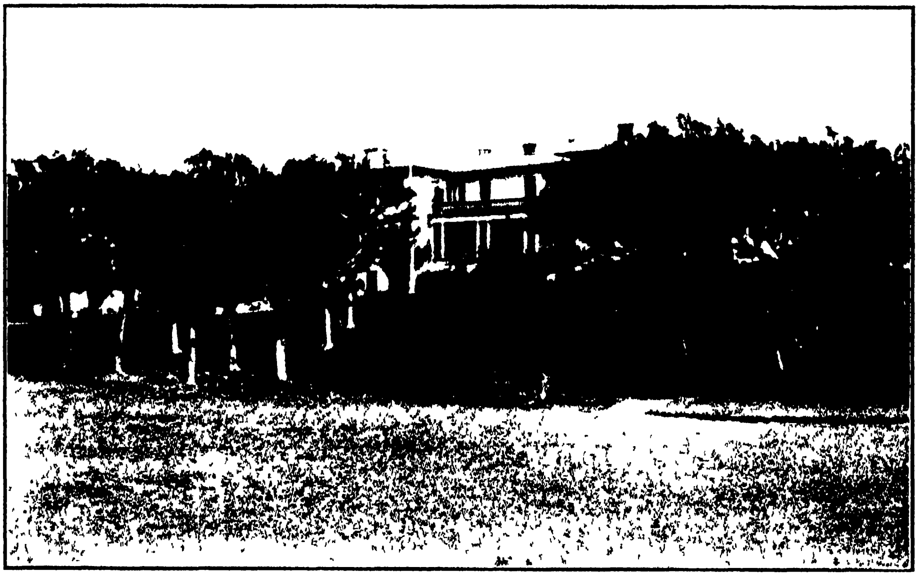
The region around Shore Hills is peculiarly favorable for biological and oceanographic work. Some of the best collecting grounds for shallow water organisms are in the near vicinity and there is easy access to coral reefs and heads and to the deep ocean. The station now possesses a small launch and several rowboats, and a larger motor boat capable of being used for deep sea work will be provided in the near future

Advantages of Bermuda for Oceanic Research

The Bermudas consist of a chain of some half dozen larger islands and many smaller ones about seven hundred miles due east from Savannah, Georgia, and nearly the same distance south from Halifax, or approximately in latitude 32° N., longitude 64° W The greater axis of these islands is about fifteen miles from northeast to southwest, and their greatest width is not more than two miles The total land area is only about twenty square miles, but there is much evidence that the land area was formerly much larger, covering about three hundred square miles Owing to subsidence and erosion most of this original land is now submerged to a depth of from one to ten fathoms, forming lagoons, sounds and harbors, while only the higher portions of the original land rise above sea level to a maximum height of two to three hundred feet.

The entire Bermuda area is really the summit of a submerged mountain which rises steeply from the ocean floor of the

LIVING ROOM, SHORE HILLS



NORTH VIEW OF SHORE HILLS FROM GOLF COURSE

North Atlantic. On all sides it slopes down more or less precipitously to depths of two miles or more. The core of this mountain is of volcanic origin, the summit is capped by aeolian limestone, and coral reefs surround most of the islands, leaving only a few ship channels into the inner lagoons and harbors.

The advantages of such a site for an oceanic station will be at once apparent. It is possible to live and work comfortably there in a modern laboratory on land and within a few minutes, in relatively small boats and at slight expense, to reach waters of abyssal depths. Only those who have experienced the difficulties and hardships of trying to do delicate scientific work on shipboard or who have some knowledge of the time and expense involved in voyages for the exploration of the deep sea are in a position to fully appreciate the advantages of having that sea brought right to the doors of the laboratory. Johannes Schmidt, who has traced European and American eels back to their breeding places in the ocean deeps south of Bermuda, has said that "Bermuda is like a research ship anchored in mid ocean," but with this significant difference—that it is a ship of great size and stability where one can live and work in comfort every month in the year in a laboratory with all modern facilities.

The greatest area of the earth still relatively unexplored is found in the deep oceans; here occur some of the most extraordinary animals that have ever been seen—animals that live in absolute darkness except for their own luminescence, in ice-cold water, under enormous pressure and in the total absence of green plants. How are they adapted to these unusual conditions? How do they obtain food and oxygen? How do they reproduce, develop and evolve in this strangest of all worlds? Dr. Beebe's studies in Bermuda have demonstrated the wealth of deep-sea life that is there available and the relative ease with which it can be obtained.

Few places in the world are so suitable for the study of the deep sea, and the same is true with respect to the various life zones of the ocean from the floating plants and animals at the sur-

BATHING PAVILION AND WHARF ON RICHARDSON'S BAY

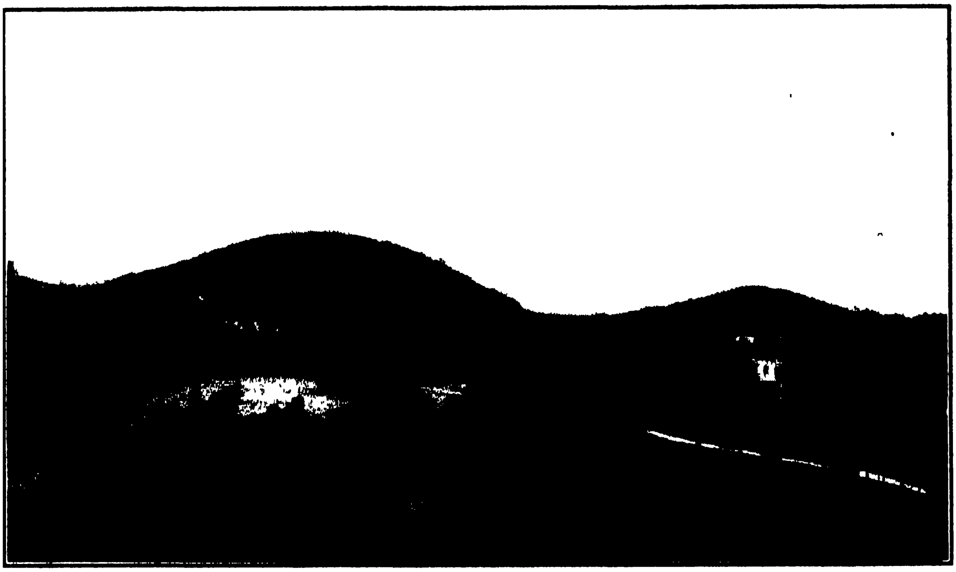
face to the actual bottom Bermuda lies within that great area of the Atlantic partially surrounded by the Equatorial Current and the Gulf Stream, and by means of these currents and the prevailing winds a wealth of floating life is drifted to its shores. Its land area is so small and it is so completely isolated from the nearest continent that one finds there almost ideal conditions for oceanic research.

In addition to these biological advantages Bermuda offers excellent opportunities for the study of the physics and chemistry of the ocean, the salinity, oxygen content and temperatures of deep-sea water, the surface currents, bottom drift and upwelling of the deeper waters, and the relation of all these to the life of these waters.

Its location makes it a very important post for the study of the weather over the great central basin of the ocean Colonel Lindbergh has said that Bermuda is destined to be an important station on transoceanic airways, and weather observatories there will be of great importance. An observatory at Prospect Hill has for many years kept daily records of the weather, but recently the Government of Bermuda has established a modern Meteorological Station at Fort George near the Biological Station Undoubtedly these two stations can cooperate to their mutual advantage, for the Meteorological Station can furnish the Biological Station with forecasts that will be of great service in its oceanic work, and the latter can furnish the former with data on ocean currents and temperatures which are important factors in the genesis of winds and storms

Because of these and other notable advantages the committee on oceanography of the National Academy of Sciences has recommended that the Bermuda Biological Station for Research be selected as the oceanic sub-station of the Woods Hole Oceanographic Institution After considering the availability and advantages of the Azores, the Canaries, the Cape Verdes, the Bahamas, the Antilles, the Florida Straits and Tortugas, the report of the committee concludes as follows:

On the whole, Bermuda seems to the committee the best situation in the North Atlantic



LOOKING NORTH OVER GOLF COURSE FROM SECOND-STORY PORCH

for investigation into the phenomena that are fundamentally characteristic of ocean basins. Its advantages may be summarized as follows:

(1) Its slopes rise so steeply from the sea floor that depths greater than 2,000 fathoms are reached within a few miles from sheltered waters. This would make it possible to carry on serious investigations at great depths with small and inexpensive vessels, and the fact that such work could be done in one-day trips would allow an advantageous unity between field and laboratory work.

(2) The Bermuda cone occupies so small an area that the fundamentally oceanic character of the neighboring waters is not disturbed thereby.

(3) There are two entirely submerged cones close to Bermuda, the "Argus" and "Challenger" banks.

(4) In spite of the precipitous nature of their slopes, the Bermuda reefs enclose a considerable and entirely protected area of shoal water, supporting a rich and varied fauna, and illustrating many phenomena of lime deposition, erosion, etc.

(5) There are several excellent harbors and sites made almost ideal for laboratory purposes by their sheltered anchorage and convenience to the open sea.

(6) All the facilities of the city of Hamilton (also of St. George), with its shipyards, shops, etc., are at hand.

(7) The climate is mild, with no extremes, favoring work the year round, while living conditions are excellent with all the amenities of modern civilization.

(8) Bermuda is conveniently reached by fast steamer from New York, and communication is good the year round.

(9) If the Bermuda Biological Station be reorganized, arrangements could probably be made for the proposed oceanographic substation to occupy part of its property at little or no expense, and this property is admirably located with its own small harbor; proximity to a well-equipped biological laboratory would be a decided advantage, especially in encouraging synthetic investigations involving both the biologic and physical aspects.

(10) The negotiations that have been carried on with regard to the reorganization of the Bermuda Biological Station have shown that the local government and population would welcome scientific activities on the island, which is a consideration of importance.

(5) Bermuda as a Sub-tropical Biological Station

Although Bermuda lies well north of the Tropic of Cancer it has a tropical and sub-tropical fauna and flora. Many tropical plants flourish there, and its coral reefs and heads, although not so rich and varied as many within the tropics, are nevertheless extensive and are the northernmost coral reefs in the

world. This northern location not only brings a sub-tropical fauna and flora near to northern centers of population, but it makes for an equable climate where the summer heat is never so great as to endanger health and the winters are very mild.

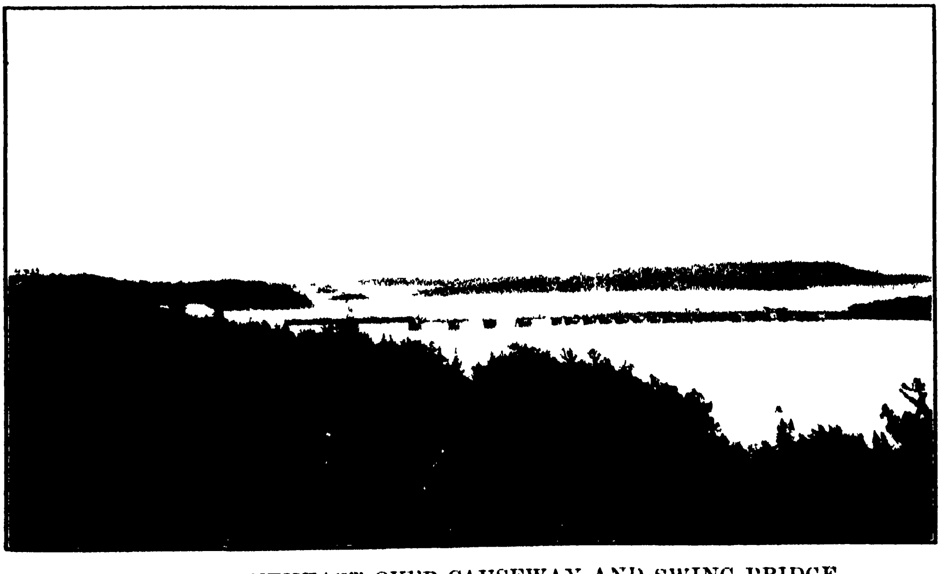
The annual reports of the observatory at Prospect for several years past show that the highest temperature recorded was 90.2° F. in September, 1929, and the lowest 44.2° in February of that year. The mean temperatures by months range from 62.9° for January to 80.5° for August, while the greatest daily range was from about 13° in June to 24° in January. As would be expected humidity is relatively high, the lowest for any month being 50 and the highest 90, the mean for all months being about 85.

The great variety of marine organisms of Bermuda has been recorded in the faunal and floral lists published by the naturalists previously mentioned, and particularly by Professor Verrill, but its extraordinary richness and interest can be best appreciated by a visit to the public aquarium at the Flatts, which is probably second to no other aquarium in the world in this respect.

The numerous lagoons, inlets, tidal pools and caves are natural aquaria of great beauty and interest, and the remarkable transparency of the water makes collecting even at considerable depths a visual rather than a blind procedure. Indeed the best method of collecting down to depths of 20 to 30 feet is by means of the diving helmet, and the charm of remaining submerged for some time in water that is comfortably warm and very transparent, and of studying animals in their natural environments is something that has to be experienced in order to be fully appreciated.

(6) Other Attractions of Bermuda

These islands, which were called by early navigators the "Devill's Ilands," and by Shakespeare in "The Tempest" "the vexed Bermoothes," and which later furnished the theme of many a poem and tale of adventure, are now



LOOKING SOUTHEAST OVER CAUSEWAY AND SWING BRIDGE
TO STOCKS HARBOR AND ST. GEORGE'S HARBOR, FROM SECOND-STORY VERANDA.

labeled by the cancellation machine of the Bermuda Post Office "The Isles of Rest." And of late it is as a resort, full of historic interest, quaintness and natural charm, that they have come to be better known. There was once a time when Bermuda potatoes and onions and lilies and fruits were their chief products, but the tourist trade has proved more profitable, and where once were cultivated fields there are now great golf courses. But in spite of this, Bermuda has not lost its charm nor been sadly "Americanized." While the tourist trade has created many hotels, developed many sports and has brought to the islands many of the comforts and conveniences of modern life, its people still guard sacredly its eighteenth century simplicity and quaintness. Automobiles are *tabu* and its narrow, winding, shaded roads and lanes are still safe for the pedestrian or the bicyclist.

Bermuda is proud of the fact that it is the oldest self-governing colony in the British Empire and that its Parliament, next to that of Westminster, is the oldest in the empire. The islands are full of historic interest, of old forts and castles and churches, of quaint houses and streets and lanes. St. George is the oldest town in the islands and in many respects the most charming, as it is least affected by modernization. The region about St. George and particularly around Shore Hills is not densely populated and is relatively unspoiled by man. The Biological Station is off the main lines of travel and will afford the seclusion necessary for intensive scientific work, and yet it is only one and a half miles from the town of St. George and not more than one fourth mile from the main highway running the length of the islands. No more delightful place of residence could be found in these "enchanting islands," and certainly no better place for scientific work.

(7) The Bermuda Station a Cooperative International Institution

It has been decided that, for the present, no charge will be made for the use of a table at the station. But since the expenses of maintaining the station will necessarily be much larger than the income now available, it is hoped that many colleges, universities and scientific institutions throughout the world will cooperate in the support of the station by subscribing at least $100 annually for the support of a table or room for a period of two months, or $500 for one year. Such subscription would entitle the cooperating institution to the use of all the general facilities of the station by an approved investigator or research student. It is also hoped that cooperating institutions may provide scholarship funds of at least $200 each to pay the traveling and living expenses of their representatives at the Bermuda Station for a period of two months, since otherwise many worthy young investigators may not be able to avail themselves of the facilities of the station. Such subscriptions and scholarships have already been provided or promised by seven universities or scientific institutions in the United States and Canada, and the widest possible cooperation, both scientific and financial, of individuals and institutions throughout the world is earnestly solicited in order that the Bermuda Biological Station for Research may be truly international in character and may be of the greatest possible service to the sciences of biology and oceanography.

DEVELOPMENT OF THE EGG AS SEEN BY THE EMBRYOLOGIST[1]

By Dr. GEORGE L. STREETER

DEPARTMENT OF EMBRYOLOGY, CARNEGIE INSTITUTION OF WASHINGTON, BALTIMORE

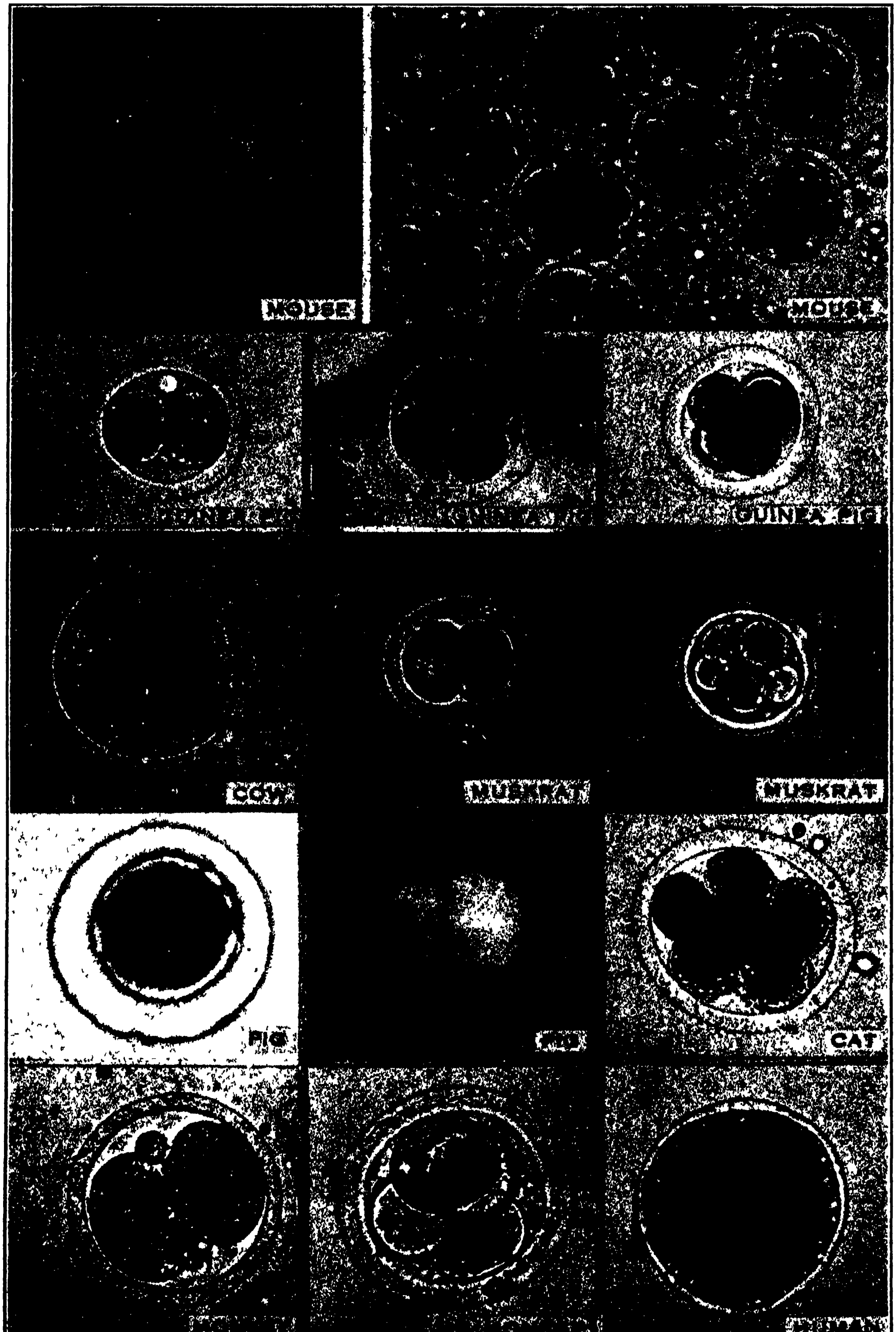
In 1827 a group of progressive business men of Baltimore incorporated the Baltimore and Ohio Railroad. They foresaw that a free pathway to the Ohio River, through its extensive water communications, would mean access to the whole interior of the continent When they laid their first tracks these early go-getters inaugurated an era in transportation that has had marvelous consequences in the development of America In that same year (1827) a German professor, Karl Ernst von Baer, discovered the mammalian egg as it occurs in the dog. His observations were published in a monograph which is now rare and is the proud possession of but a few of our American libraries Though a century has passed one would hesitate to claim that von Baer's discovery has thus far had any consequences whatever on the development of the United States.

In the next one hundred years, however, the relative importance of knowledge of the mammalian egg and knowledge of railroad engineering may be entirely reversed. There are indeed many reasons for thinking that railroads have already attained their best development and are now on the decline, being destined to yield eventually to the competition of other means of transportation. With the mammalian egg the situation is different. We are only just beginning to realize to what extent human welfare is dependent on its structure and its proper performance. It is only in recent years that ways have been devised for observing, testing and experimenting upon such a small object. Enough progress has already been attained, however, to lead one to predict great things of the future. We may never learn all the factors which determine how man comes to be as he is, but some of them appear to be within our grasp. It is my purpose to refer to these things and by means of photographs to show eggs of several different mammalian kinds and to follow the mysterious manner in which they become transformed into embryos, and in turn recognizable animals, and most of all I wish finally to impress upon the reader that the kind of material with which he starts his separate existence is of tremendous importance to him.

The mammalian egg is much simpler than a hen's egg. In the bird there are several auxiliary structures, such as the shell, air chambers, masses of albumen and yolk, which are contrivances suited to the peculiar needs of creatures that develop by hatching. When stripped of all such accessories, as is the case in placental animals, the egg, quite uniformly in both larger and smaller animals, is a very small thing, barely visible to the naked eye. It can be seen if properly illuminated against a black background as a tiny white particle.

By rinsing out the reproductive tract in an animal like the rabbit and by using a delicate glass pipette one can transfer the fertilized eggs to a small glass dish, filled with suitable fluid, and kept at body temperature. Thus installed under the microscope the living eggs can be studied and the stages in

[1] From a symposium on development given at the Carnegie Institution of Washington in November, 1930.


MOUSE
MOUSE
GUINEA PIG
COW
MUSKRAT
MUSKRAT
PIG
CAT

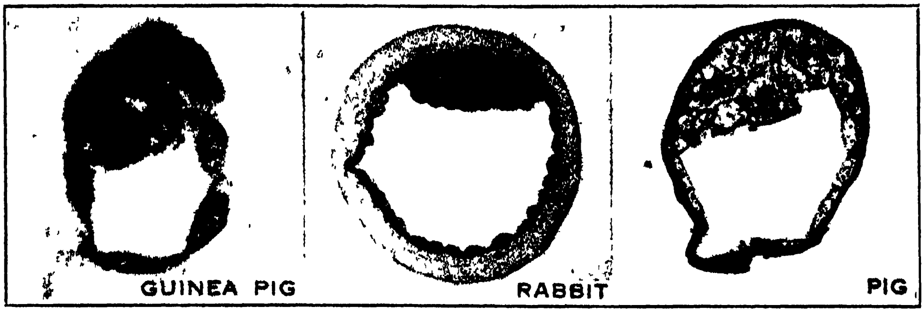


FIG 2. SECTIONS SHOWING THREE TYPICAL BLASTOCYSTS

BY THIS TIME THE FLATTENED TROPHOBLAST CELLS CAN BE DISTINGUISHED FROM THE MORE PRIMITIVE CELLS OF THE INNER CELL MASS. THE TROPHOBLAST CELLS ARE ALREADY FUNCTIONING TO THE EXTENT OF PASSING FLUID THROUGH INTO THE CENTRAL RESERVOIR, OR SEGMENTATION CAVITY FOR THE SECTION OF THE GUINEA PIG OVUM I AM INDEBTED TO DR N MACLAREN, GLASGOW.

their development followed step by step for several days. Photographs of living eggs of various mammals which have been studied in this way are shown in Fig 1.

In studying the recently fertilized living egg, one first of all notices that it possesses a translucent protective capsule. This is a temporary structure which soon disappears, and beyond mentioning its pleasant sounding name *Zona pellucida* need not further concern us. Our interest lies in the body that lies within it, as a single cell. If this cell is watched, one presently sees an increasing agitation of its protoplasmic granules, creating a summation of force that eventually terminates in a rending of the cell into two halves Thus, the single cell, originally composing the egg, separates into two cells and these daughter cells each in turn divide and so on, until in a few days there are many cells.

Now cell division is not to be confused with growth, although it underlies it In this case it simply means that the single mass of protoplasm with which we started has separated into smaller and smaller units with no increase in total volume. It is known technically as cleavage One purpose of this appears to be the segregation of the materials of the egg, as a foundation for the division of labor that will be necessary in the more mature organism Even at the first division the two daughter cells are not identical One of them is likely to be larger than the other, and the larger of the two is likely to divide sooner, thus showing a beginning difference both in structure and behavior One must assume that in the division the two halves receive different proportions of the original protoplasmic substances To say that daughter cells make an uneven division of their heritage is, of course, a crude way to state it To say anything more precise at the present time would be highly speculative The embryologists are studying these things assiduously and are talking in terms of attraction and repulsion, surface tension, cohesion and dispersion, difference

FIG. 1. LIVING MAMMALIAN EGGS IN EARLY CLEAVAGE STAGES

ALL ENLARGED 200 DIAMETERS. THESE PHOTOGRAPHS WERE RECENTLY MADE, AND IN MOST CASES THE STUDIES FOR WHICH THEY WERE OBTAINED HAVE NOT YET APPEARED. THE AUTHOR IS INDEBTED TO THE FOLLOWING PERSONS FOR PERMISSION TO MAKE ADVANCED USE OF THEM: MOUSE: W. H. LEWIS; GUINEA PIG, R. R SQUIER; COW, HARTMAN, LEWIS, MILLER AND SWETT; MUSKRAT, C. H. HEUSER AND R. R. SQUIER; CAT, R. R. SQUIER; MONKEY (*Macacus rhesus*), W. H LEWIS AND C. G. HARTMAN; HUMAN TUBAL OVUM, W. H. LEWIS

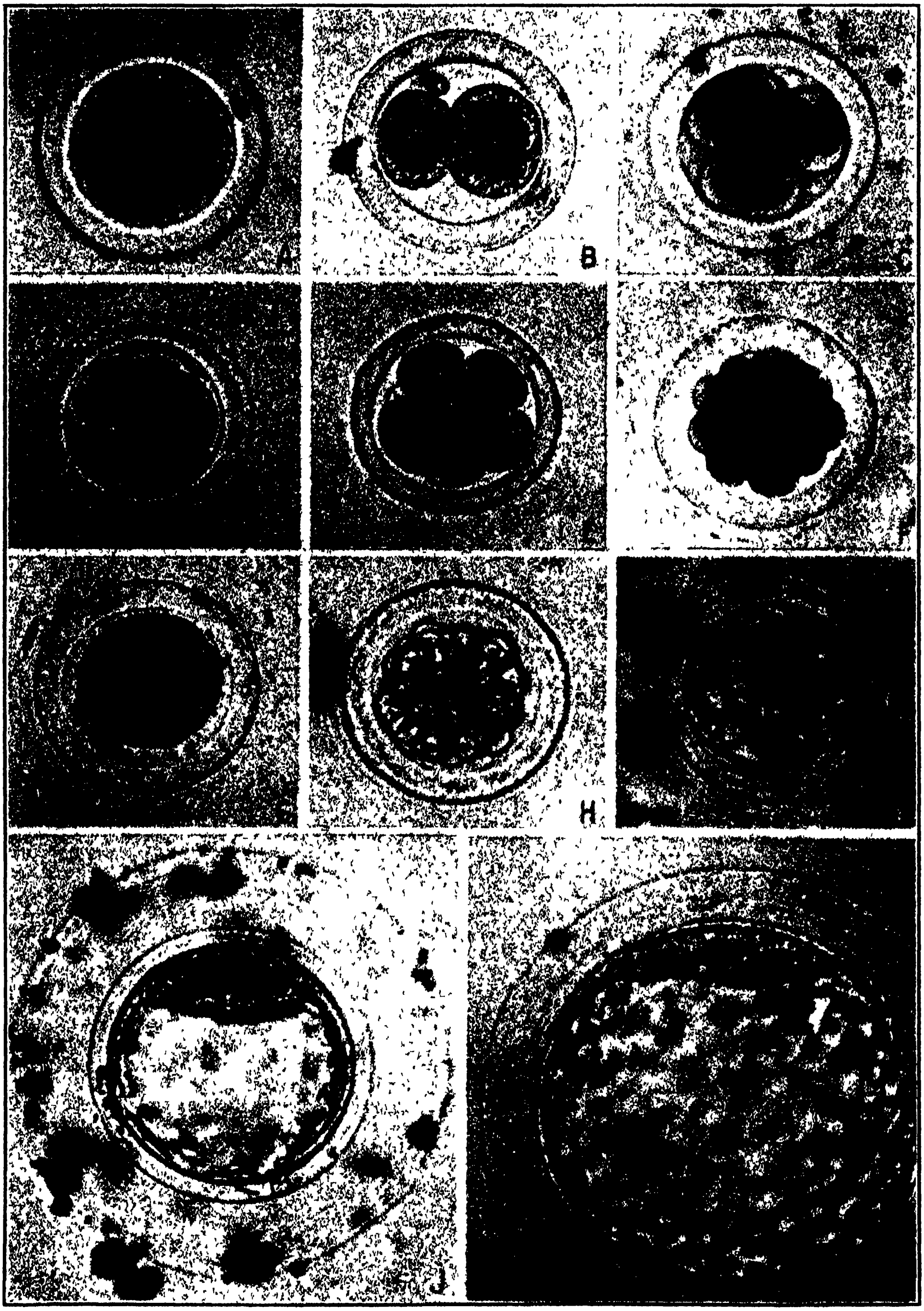


FIG. 3. THE RABBIT OVUM

PHOTOGRAPHS OF THE LIVING EGGS IN A SERIES OF STAGES SHOWING CLEAVAGE, DIFFERENTIATION OF THE TROPHOBLAST, FORMATION OF THE SEGMENTATION CAVITY AND THE DEMARCATION OF THE INNER-CELL MASS, FROM WHICH THE EMBRYO IS FINALLY DERIVED. ENLARGED 180 DIAMETERS. (P. W. GREGORY, "EARLY STAGES IN THE DEVELOPMENT OF THE RABBIT EGG." CONTRIB. TO EMBRYOL. VOL. 21, CARNEGIE INST. WASH., PUB. 407, 1930).

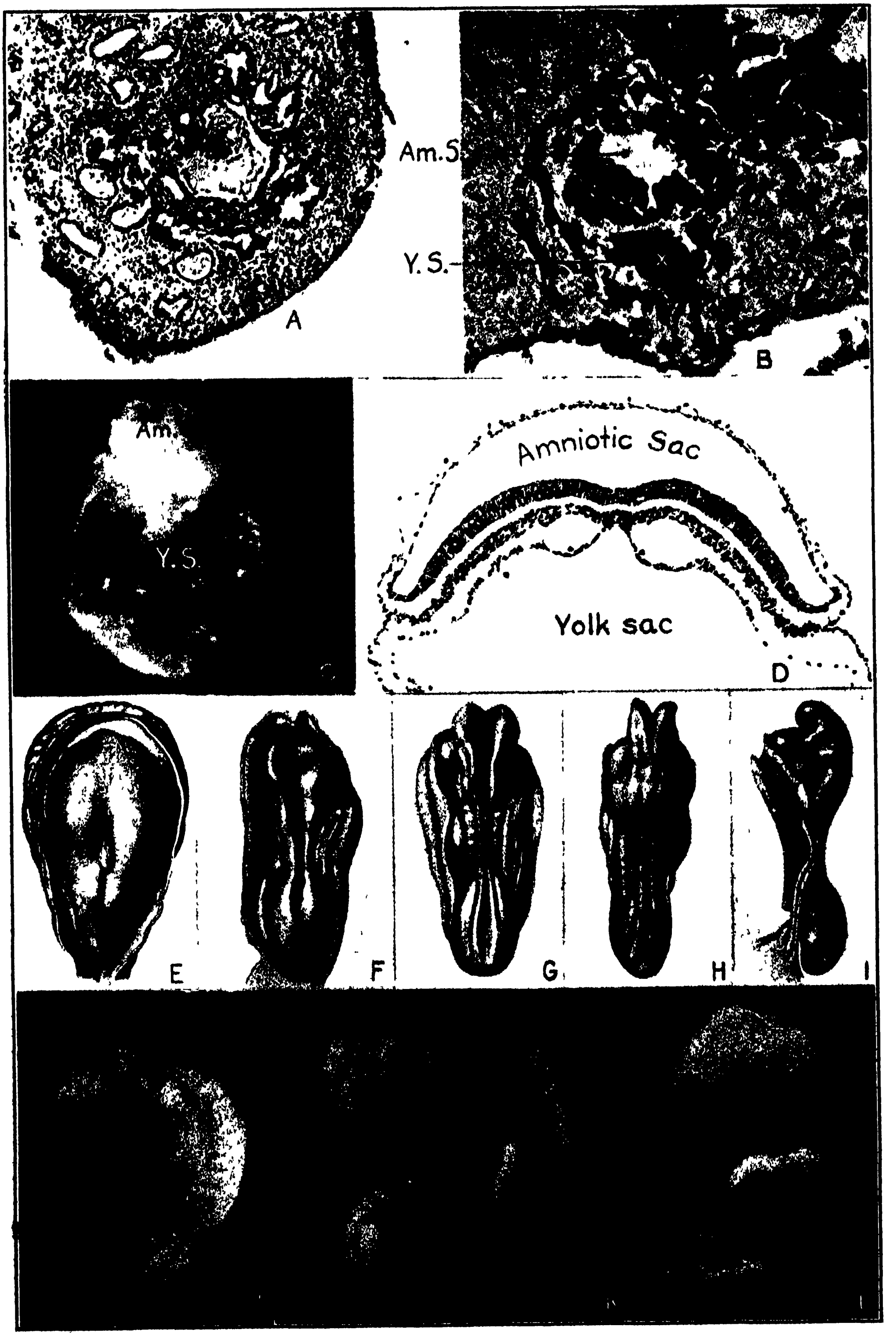
in potentials and electric charges and hydrogen-ion concentrations. In some of these factors, apparently, an explanation of cell division is going to be obtained, and in the meantime it behooves us to await patiently the outcome of their labors.

After a few divisions, the differences between the cells become more pronounced. One finds, for instance, that the material that is to form the implantation-mechanism and fetal membranes, the so-called trophoblast, has already at the 16-cell stage separated off from the material that is to form the embryo proper The trophoblast is the most precocious part of the egg, its cells divide more rapidly and consequently are smaller and soon begin to show specialization in structure, or as the biologist would say become differentiated. They stand out, in marked contrast to the slowly dividing and more primitive appearing remainder of the egg, the inner-cell mass that is to form the embryo From then on these two parts of the egg run separate courses and can not change one into the other. The histologist is thus provided with his primal classification for all the subsequent tissue derivatives

In a sketchy way from what has been said and from Fig. 1 we have seen what the mammalian egg is like. We have seen how it undergoes cleavage into many small cells. We have learned something of the consequences in the way of segregation and differentiation of the precocious trophoblast. Let us pass on to a phenomenon that at this point occurs in the eggs of all placental animals. They become transformed into *blastocysts*, which is another way of saying that the cells of a given egg which originally were clumped as a solid mass become arranged as a hollow fluid-containing sphere Three typical blastocysts are shown in Fig. 2. Why mammalian eggs become blastocysts can be explained in two ways: Some would say that it is reversion to, or souvenir of, some primitive ancestral type; others, and I think rightly, see in it nothing more than a necessary preparation for the attachment of the egg to the maternal tissues. Certain it is that in all cases the blastocyst wall forms an isolating envelope for the embryo and at the same time it provides an expanded membrane which establishes a large contact with the maternal tissues, favorable for subsequent interchange of fluids between mother and embryo.

As we have already noticed, the trophoblast cells in dividing arrange themselves in a single layer at the surface of the egg, like a membrane, and they also become more mature in appearance. No sooner does this happen than one begins to see lakelets of clear fluid collecting within the egg, the physiological expression of the secretory activity of these newly matured trophoblast cells. As the fluid increases the trophoblast membrane is crowded away from the inner-cell mass and the lakelets coalesce as a common central reservoir. The egg is thus converted into a thin-walled vesicle tensely distended with fluid It is when eggs reach this stage that they are given the title of blastocyst Up to this time the egg has become no larger than it was at the outset, but now growth begins and the increase in size of the egg is in proportion to the increase of the fluid with which it is distending itself.

It should be explained that cleavage of the egg into small units and the differentiation of the cells and their arrangements into a blastocyst take place very gradually, so slowly that if watched with the naked eye the changes would not be detected. Were it not for motion-pictures, one would not have been able to speak so definitely about what happens in the egg as I am doing in this paper. It is well known that by


Am.S
Y.S.
A
B
Am.
Y.S.
Amniotic Sac
Yolk sac
D
E
F
G
H
I

motion-picture photography one can take pictures slowly and then project them rapidly, thus revealing movements otherwise imperceptible It was a great boon to embryology when it was found that this technique could be applied to the study of microscopic objects like an egg. A triumph in this direction is the Lewis-Gregory film of the developing rabbit egg, which has thrown much light on nature's marvelous way of transforming a single cell into a blastocyst. The more important stages in the cleavage of a mammalian egg and its transformation into a blastocyst are shown in Fig. 3.

Now that the complexities of the blastocyst have been mastered we are in a position to direct our attention to man. It is at the blastocyst stage that our knowledge of the human embryo begins. The youngest known human specimen in which the embryo can be seen is a blastocyst that has just become lodged in the maternal tissues and its age is reckoned at eleven days. All the ova thus far considered have been free blastocysts. This human attached specimen differs in having a great elaboration of its trophoblastic wall. It is apparently by virtue of the latter that the penetration of the maternal tissues is accomplished, technically known as implantation, and throughout pregnancy this trophoblastic shell continues to have a profound effect upon the surrounding tissues. The details of this we will not take up. It is sufficient to know that it forms a protective sac that incloses the embryo and also provides for its nourishment.

Thus far very little has been said about the inner-cell mass. But the last shall not be least Our belated attention will now be entirely concentrated on these important cells, for they are the ones that form the embryo proper. Lying in the center or toward one side of the egg, they show little sign of change or activity until the trophoblastic shell has provided the proper setting. With that accomplished, the inner-cell mass begins the active assertion of its prerogatives, namely: segmentation, readjustment in position and differentiation. These cells form an embryo in about the same way in the various kinds of mammals with only minor differences In man, the first thing they do is to arrange themselves as two preliminary vesicles, the *amniotic vesicle* and the *yolk-sac vesicle*. These vesicles become vesiculated in much the same way as the egg managed it, when it changed from a solid cell-mass to a blastocyst. It is a clever developmental device, and we see examples of the same or similar phenomena in the subsequent formation of individual organs. We next find these two vesicles flattening against each other, and where they come in contact they form a bilaminar plate. It is this two-layered plate, or germ-disk, and only this, that forms the embryo. The remainder is accessory and temporary, as much so as the trophoblast.

When the germ-disk is formed and these two layers come together new

FIG. 4. HUMAN EMBRYOGENESIS

A, THE MILLER OVUM, A BLASTOCYST EMBEDDED IN UTERINE WALL, ABOUT 11 DAYS. B, DETAIL OF INNER-CELL MASS OF SAME OVUM, ENLARGED × 250 C, EMBRYO NO. 3,412, ABOUT 14 DAYS, AMNIOTIC SAC ABOVE, TRANSPARENT YOLK SAC BELOW; D, TRANSVERSE SECTION OF EMBRYO NO. 5,960, ABOUT 16 DAYS, SHOWING GERM DISK WHICH GIVES RISE TO THE EMBRYO. IT CONSISTS OF THE PORTIONS OF THE TWO SACS THAT ARE CONTACT AND THE INTERMEDIATE LAYER THAT FORMS BETWEEN THEM. E, MODEL OF SAME EMBRYO, × 30, ROOF OF AMNIOTIC SAC REMOVED EXPOSING FLOOR OF GERM-DISK. F, INGALLS' EMBRYO, × 28, ABOUT 18 DAYS. G, PAYNE EMBRYO, × 23, ABOUT 19 DAYS. H, CORNER EMBRYO, × 23, ABOUT 20 DAYS. I, ATWELL EMBRYO, × 15.5, ABOUT 22 DAYS. J, EMBRYO NO. 6,097, × 12, ABOUT FOURTH WEEK. K, EMBRYO NO. 1,380, × 8.5, ABOUT FIFTH WEEK. L, EMBRYO NO. 6,202, × 2.5, ABOUT EIGHTH WEEK.

things begin to happen and the developmental tempo speeds up. The two layers are different in character and they interact on each other. This results in the differentiation of new types of cells. As new cells arise new interactions take place, producing other new cells which in turn give rise to further new reactions. In consequence we have not only the new kinds of cells that are provided by segregation and intrinsic differentiation but also those that are derived from the influence of one kind upon another and from other environmental interactions. The structure of our tissues thus becomes progressively more intricate and we begin to speak of organs and definite body parts.

The gross aspects of human embryogenesis are shown in Fig 4. Starting with the Miller ovum (A and B) one recognizes a blastocyst submerged in the uterine tissue. Its wall is highly elaborated and its cavity is filled with coagulated plasma. In the plasma can be seen the inner-cell mass, especially in B, where under higher magnification its details are better shown. The inner-cell mass forms two main cell aggregations, one of which in Fig B has already taken the form of a vesicle, the other soon does the same and so we have an amniotic vesicle and a yolk sac vesicle. These can be seen in Fig. C in a slightly older embryo. The thin transparent yolk sac is below and the flattened amniotic sac is above, being opaque, due to its thick floor. D is a transverse section through a similar embryo showing the amniotic vesicle above and a portion of the yolk sac below. Between them a new layer of cells has formed, the mesoblast cells. When the amniotic sac and the yolk sac come in contact, together with the cells that are proliferated between them, there arises a trilaminar plate or germ-disk, and it is this that gives origin to the body of the embryo. At first flat or slightly convex, it becomes converted by thickened longitudinal ridges into a tubular or larva-like body, the successive stages of which are shown in Figs. F to I. This occurs during the third and beginning of the fourth week. There then follow the changes of the second month shown in Figs. J to L. By the end of the second month the principal external features of the body can be recognized and our specimen acquires the status of fetus and is thereafter so designated.

Our briefly told drama of the origin of a new individual is all but finished. There only remains now for it to grow bigger and better and to live happily ever after. But this drama has an epilogue and I am sorry to say a somber one. For the individual doesn't always grow bigger and better, and doesn't always live happily ever after. Eggs are not all alike. We can no longer take the view that an egg is just an egg—with nothing more to be said about it—a kind of biological molecule which is fixed and fast and necessarily perfect at the outset.

There is the common expression "as like as peas in a pod." But the farmer knows that peas in a pod are not alike He has learned to be very particular about the peas he plants and, moreover, with every kind of seed with which he deals. The butter and egg man prudently notes the size of hens' eggs and whether or not they are fresh. But the poultry raiser needs to know more than this. He has been taught that the hatching quality of eggs is an innate constitutional character, therefore he inquires about their family history. If one takes a clump of frog's eggs and places them under slightly unfavorable conditions, it is found that some of the eggs develop and others do not. By regulating the severity of the environment one can nicely control the number that will fail to develop. The eggs are not alike in their ability to develop in face of hard-

ships. It has been shown in the pig, where there are litters of approximately twelve eggs, all subject to the same environment, that as many as 25 per cent. of the eggs shed are not good enough to reach birth as living individuals. The failures are found in the reproductive tract, arrested in various stages of development in proportion to the degree of their poor quality. A similar incidence appears to be true for man and it is just such specimens that make up a large part of the material that the physician encounters in arrested pregnancies.

The importance of quality of the egg, and of course I include both its maternal and paternal elements, is not limited to uterine life Whether the infant survives its first year depends in considerable part on the original quality of the egg If they withstand the usual wear and tear of life until between fifty and sixty years they conform to the actuary's expectation of life at birth—and to the embryologist's expectation of the performance of an egg of average quality It is only the extraordinarily good egg that is still going strong at 80 years, and we see him (or her) do this in the absence of any exquisite hygienic régime or environmental favor

We have been speaking of the egg as a whole and have pointed out that it develops and lives in proportion to the vitality with which it is endowed. Good eggs produce hardy long-lived individuals and poor eggs succumb during intra-uterine life, infancy or early years of maturity. The egg as a whole, of course, consists of a multitude of elements and it is the sum and integration of these that determines its fate. Thus, if we would know the quality of the egg we must determine the quality of its parts. As a whole the egg may be a satisfactorily performing mechanism, although certain portions of it are of inferior quality. One finds, in fact, that it is normal for the component elements of the egg to differ among themselves in such qualities as endurance, vulnerability and capacity for growth. One also finds that these differences vary in different eggs and that they are hereditary. Our body is not like the deacon's masterpiece that went to pieces "all at once and nothing first." We are more like the automobile, made of materials of unequal durability, which reaches the automobile graveyard while much of it is still strong and intact. Similarly in the autopsy room we see human mechanisms which are wrecked only because of injury or defect of some single critical organ, for the loss of which the body could not compensate. In numerous unimportant functions the unequal endurance of our various tissues is a matter of common observations. We take it for granted that our teeth are going to yield to decay early We expect to use spectacles at fifty years. In some families the hair becomes streaked with gray in early adult life. In other families the hair follicles themselves, normal enough in earlier years, degenerate prematurely, with genetic precision, in spite of the most desperate efforts to prevent it. On the other hand, some of our tissues are super-tissues which do their work easily without sign of wearing out and appear capable of a much greater life span than is granted them. Some of our tissues have the power of self-replacement and it would appear possible for such to carry on indefinitely.

These ordinary differences in tissue quality found in the normal individual intergrade with cases where the differences are more extreme One then begins to speak of them in terms of disease and they become of more serious consequence. Under this heading would come such afflictions as familial retinitis, an inheritable condition in which the retina after functioning normally in youth degenerates in the earlier years of adult life with resultant blindness.

An analogous inheritable deterioration occurs in the organ of hearing, and such families have learned to dread premature deafness. To these might be added many obscure degenerative changes that attack nerve and muscle tissues in middle life. It is also probable that degenerative diseases of the heart and blood vessels are to be explained as well by the constitution of the germ-plasm with which the individual started life (that is, the inherited vulnerability of his vascular system) as by the much blamed overwork, overeating, oversmoking and overdrinking, which in other individuals do not result in a comparable damage.

The Health Department of Baltimore publishes annual mortality tables, like other large cities, and there one sees the causes of death tabulated in various ways. In addition to being a black-list of undesirable afflictions, perusal of these tables reveals that deaths from a given disease do not in general occur at a sharply circumscribed time of life but are widely spread over the older age periods. This becomes intelligible if one accepts the point of view that there is an egg-determined life span and an egg-determined vitality of individual organs. Those persons, for instance, who are destined to die of cerebral apoplexy are found to meet their fate

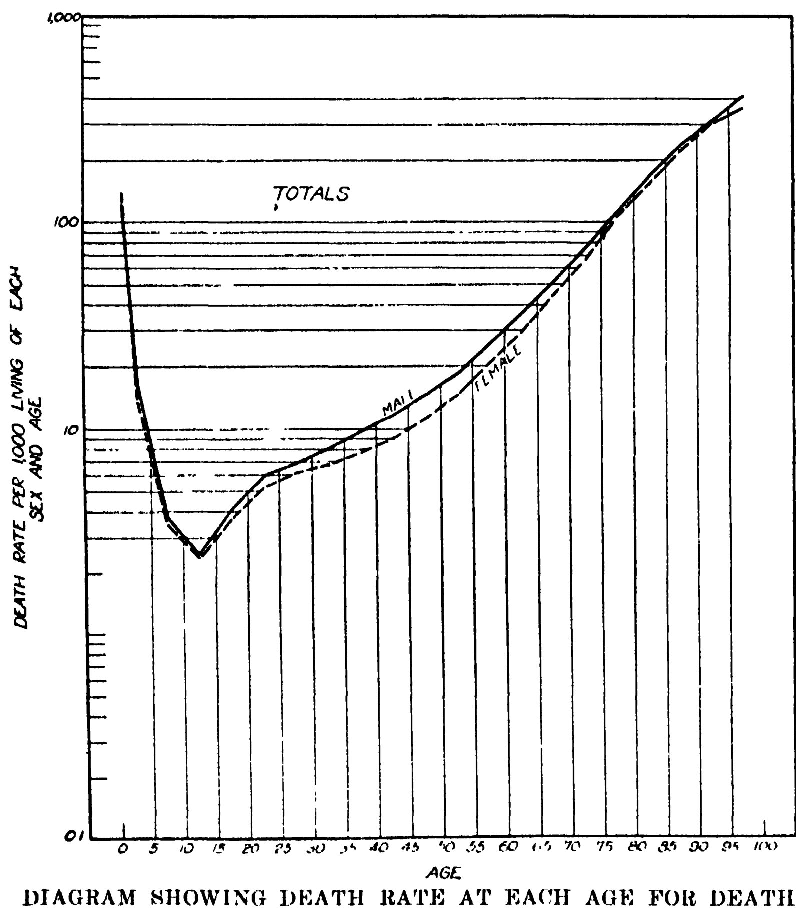


FIG. 5. DIAGRAM SHOWING DEATH RATE AT EACH AGE FOR DEATHS FROM ALL CAUSES TAKEN TOGETHER
(PEARL, "THE BIOLOGY OF DEATH," LIPPINCOTT AND CO., PHILADELPHIA.)

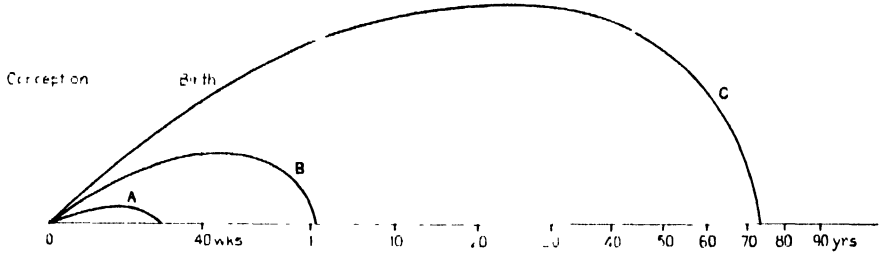


FIG. 6. A SCHEMA IN WHICH QUALITY OR ENERGY OF THE EGG IS REPRESENTED AS A CONTROLLING ELEMENT IN LONGEVITY

LIFE IS SHOWN AS A BALLISTIC CURVE, THE FORM AND SPAN OF WHICH ARE DETERMINED BY TWO FACTORS, NAMELY: THE INITIAL QUALITY OF THE EGG AND THE RESISTANCE IT MEETS IN ITS FURTHER COURSE. IN THE THREE CURVES, CHOSEN AS TYPICAL, IT IS ASSUMED THAT THESE INDIVIDUALS ENCOUNTER THE COMMON WEAR AND TEAR OF EXISTENCE THE DIFFERENCE IN THEIR LIFE SPAN RESULTS ENTIRELY FROM THE DIFFERENCE IN THEIR INITIAL QUALITY. WERE THE WEAR AND TEAR GREATER OR LESS THE CURVES WOULD BE CORRESPONDINGLY ALTERED IN SUCH A SCHEMA THE RELATIVE INITIAL QUALITY OF THE EGG CAN BE EXPRESSED IN TERMS OF DEGREES OF THE ANGLE OF PRIMARY INCLINATION.

at various ages from forty to eighty years and more, in accordance with their individual vulnerability to that type of deterioration. The same is found true for malignant tumors, diseases of the heart, cirrhosis of the liver and chronic nephritis In other words, the age levels in mortality tables are not determined solely by the nature of the diseases but are equally dependent on the extent of vulnerabilities of the individuals affected.

A mortality curve based on a large amount of data showing deaths from all causes is reproduced in Fig 5. It will be seen that the number of deaths is very high immediately after birth. Falling abruptly, the mortality curve is lowest at about eleven years. From that point it gradually ascends until the oldest ages are all gathered in This is as one would expect it, except for the excessive infant mortality. Vigorous efforts have been made to reduce the latter and with some success, but it is still a dangerous thing to be under one year old. The reader may be surprised to learn that 10 per cent. of all deaths in Baltimore last year (1929) were recruited from this age-group, and in former years the proportion has been nearer 20 per cent. This large infant mortality, however, can be understood if one remembers the change in living conditions the infant meets at birth. In the prenatal state he enjoys highly favorable arrangements in respect to temperature, respiration, food supply and absence of infections; and even fetuses of poor quality can make a "go" of it But with the advent of birth the less well-endowed babies are not able to survive and nature's first great sorting of the fit from the unfit takes place with its terrible toll.

The traditional concept of disease and death portrays for us a grim reaper who, stalking about with scythe and hour-glass, embraces with his bony arms the unwary laborer at his task Death has been conceived of as a horrid person who to some extent can be eluded through magical charms, cleverness or divine aid. The classical way of life (Fig. 7) is a uniform procession from infancy to tottering old age, any de-

parture from which is abnormal. In more recent times disease, for the most part, became the consequence of various evil microscopic organisms or injurious viruses, and when all these were eradicated from the surface of the earth universal well-being would prevail. We still to-day think of germs as evil, but other factors have entered. We have learned that the same germ is not equally injurious to all persons. The campaign on their complete eradication is slackening and the problem has been shifting to the matter of individual resistance. Instead of the traditional concept of life of Fig. 7, a new schema must therefore be substituted in which the span of life is determined by two opposing factors, namely, the initial energy or quality of the egg and the resistances it subsequently encounters.

It is not my intention to proceed further with the complicated problem of disease or with the various factors that underlie body defects and death. But I hope some impression has been conveyed as to what man is like at the beginning and that my thesis has been made clear that this tiny egg contains not only his possibilities in the way of morphological characteristics and mental attainments but also determines what endurance he is to have in meeting the various vicissitudes of life that are lying in wait for him. Let us hope that he is a good egg!

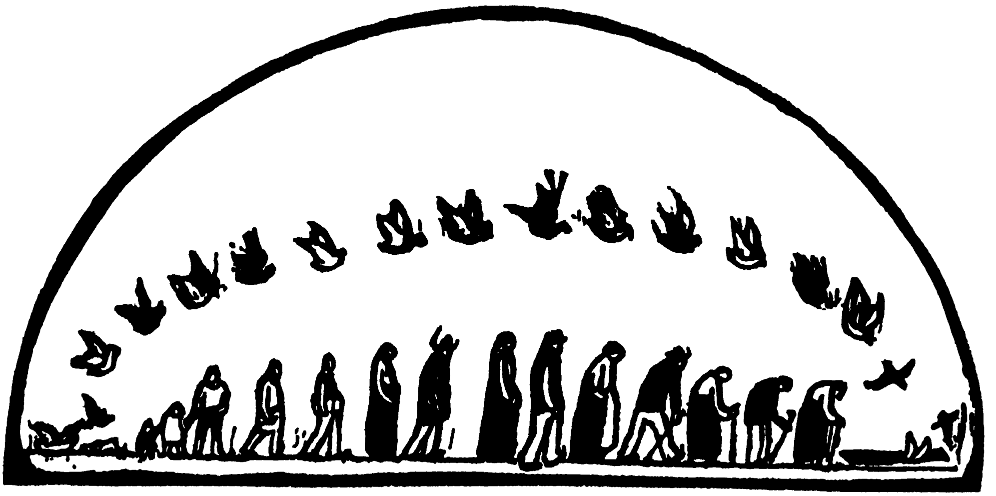


FIG. 7. THE WAY OF LIFE: BY FRANCESCO GAMBA
REPRODUCED IN THE *Baltimore Sun*, OCTOBER, 1930.

SCIENCE IN THE LIVE-STOCK INDUSTRY

By Dr. J. R. MOHLER

CHIEF, BUREAU OF ANIMAL INDUSTRY, U. S. DEPARTMENT OF AGRICULTURE

THE influence of science and invention in the industrial world is so familiar that there is a tendency perhaps to associate scientific discoveries principally with developments in that field. Revolving wheels, electrical wires and new commodities confront the American public constantly. Hence it is natural that mechanical, electrical and chemical advancement should attract particular attention.

SCIENCE AIDS NATURAL PROCESSES

The forces of science are also operating steadily and in a most interesting manner on life itself and the effects are especially visible in our domestic animals. Live stock in the United States are much more numerous than the human population, and since their breeding, feeding and general care are under close human control, the effects of scientific methods are readily seen to be on a large scale.

Without the knowledge which science has given producers and distributors of live-stock products, the present supply would be materially less, of lower quality and probably of greater cost to consumers. Without scientific knowledge the delivery of pure, safe milk in large cities would be severely restricted; the supply of desirable wool and leather would be uncertain; and ham and eggs would doubtless be found less often on our breakfast tables. Among the devel-

A TON LITTER,

MEANING THAT THE PROGENY OF ONE SOW WEIGHED TWO THOUSAND POUNDS OR MORE AT 180 DAYS OF AGE. THIS LITTER EXCEEDED THE REQUIREMENT, ATTAINING A WEIGHT OF 2,910 POUNDS.

COMPARISON OF LONGHORN STEER

OF THE TYPE COMMON FIFTY YEARS AGO, WITH AN IMPROVED BEEF ANIMAL OF TO DAY

opments largely responsible for improved conditions in animal production are methods expressed through veterinary science, refrigeration, pasteurization, meat inspection and numerous related activities.

Unlike human beings who protect their health by adequate housing, sanitary sewage disposal, cooking of their food, use of screens and other familiar safeguards, domestic animals are constantly exposed to bacterial and parasitic dangers. Besides, the attention given to their health and welfare is determined largely by their commercial value. A stock owner is unlikely to spend more on the treatment of an animal than the animal is worth. In fact, he could not afford to do so as a general practice. Hence the profitable production of our domestic live stock involves painstaking methods to prevent animal ills as well as exceptional efficiency in feeding, housing and general care. Fortunately, scientific study has developed many satisfactory methods of preserving live-stock health and improving animal types.

Research Solves Live-stock Mysteries

A half century ago many mysterious losses beset the business of producing domestic animals. In parts of the Southwest, cattle and horses were observed to go "crazy," and in the intermountain region large numbers of sheep apparently in the best of health one day would be found dead the next morning without visible signs of the cause.

Cattle owners in the South were perplexed by the "bloody murrain" which killed thousands of cattle and reduced others to an unthrifty, stunted condition. The number raised to market condition was, in large degree, a matter of chance Various economic factors likewise were involved and in some in-

stances state and local legislation was a material factor, as in the case of laws to restrict the ravages of sheep-killing dogs.

In those days a visitor to the farms and ranches of the United States observed materially different types of animals than are seen to-day. Cattle had larger heads, longer horns and smaller bodies. Besides, they required a much longer time to reach market size and condition than they do to-day. Hogs were faster on foot but slower in growth and besides were at the mercy of the then unchecked scourge, hog cholera.

As time went on, stockmen learned that in dealing with many specialized problems long experience counted but little. Personal courage and aggressiveness could check the inroads of cattle rustlers and other visible enemies, but were powerless against the elusive contagion of animal disease. This condition resulted, in 1884, in the establishment of the Bureau of Animal Industry in the United States Department of Agriculture. The same or similar problems also stimulated research and experimentation in various state institutions and were largely responsible for the development of agricultural experiment stations.

Animal Diseases Brought under Control

It is true that "book farming" did not appeal to many veteran stockmen at first, and some of the scientific explanations and proposed remedies for various troubles fell on unbelieving ears. When the Bureau of Animal Industry announced that the bloody murrain was a fever carried and transmitted by cattle ticks, there was skepticism, and when the work of eradicating ticks by dipping cattle in an arsenical solution of tested strength began, there was opposition, often of violent nature Dipping vats were destroyed by lawless persons who objected to the innovations which they felt were being forced upon them. But time gradually demonstrated the soundness of the scientists' recommendations. In the case of tick fever, 82 per cent. of the territory formerly infested has been freed of the disease by systematic dipping of ticky cattle The average progress has amounted to about 25,000 square miles annually.

The discovery by the same bureau of

PORTION OF DAIRY HERD OFFICIALLY ACCREDITED AS FREE FROM TUBERCULOSIS.

WOOL IN THE MAKING.
THE PRODUCTION OF FINE WOOL HAS BEEN MATERIALLY AIDED BY ANIMAL HUSBANDRY RESEARCH.

a preventive serum for hog cholera restored confidence in swine production and the manufacture of the serum is now an extensive industry. This safeguard to hog health is especially valuable in regions, such as the Corn Belt, where swine are raised in large herds and where an outbreak of disease among susceptible animals would have far-reaching and ruinous consequences As a further help to hog-raisers, correct methods of using the preventive-serum treatment are demonstrated by veterinarians of the bureau who are especially trained in hog-cholera-control work.

During the last twelve years the Department of Agriculture, cooperating with the states, has waged an aggressive war likewise against bovine tuberculosis. As a result the average extent of tuberculous infection among cattle has decreased from more than 4 per cent. to 1.7 per cent. In approximately 1,100 counties which have been especially energetic in the systematic testing of cattle within their borders, the infection is known to be less than one half of 1 per cent. Scientific discovery, utilized in a definite plan of field operations, has made this kind of progress possible. In recent years the work of eradicating tuberculosis has been extended likewise to swine and poultry, with encouraging results.

UTILITY OF LIVE STOCK IS INCREASED

Simultaneously with the conquest over various animal ills, investigators in live-stock breeding have demonstrated how stockmen may control the size, form and general appearance of their animals through knowledge of the laws of heredity. This knowledge is now recognized as a practical means for increasing the utility value of domestic animals as well as for controlling color, horn development and other qualities. Thus, through knowledge of animal breeding, the modern stockman has virtually become a sculptor in living flesh and the most able breeders are virtually designers of the latest models of domestic live stock. Through breed associations and live-stock shows and expositions, the types of animals considered most desirable for present needs are publicly recognized and awarded prizes. The types naturally vary, depending on

the purpose for which raised. Accordingly, there are well-marked differences between cattle for beef and dairy purposes, horses for light-harness and draft service, and between sheep intended primarily for the production of wool as contrasted with the so-called mutton breeds.

Besides aiding live-stock producers in safeguarding their investment and increasing the usefulness of their animals scientific research continues to make still other valuable contributions It has furnished a simple and accurate test for the fat content of milk and investigators are now conducting intricate studies on the quality and palatability of meat Research has determined, for instance, that the hatchability of eggs is influenced by such factors as inbreeding of the parent stock and by the quantity of animal protein in the feed of hens, as well as by conditions of incubation

Science likewise has furnished the background for the extensive federal meat-inspection service which supervises all processes in the slaughter of about 75 million head of stock annually and the handling of their meat. In this work veterinarians, pathologists, chemists and sanitary experts all contribute to the highly efficient system that is now accepted as a necessary part of modern living

Considering that live stock have been kept by man for fully 50 centuries, it is indeed noteworthy that the last 50 years have witnessed the most outstanding progress in breeding and raising domestic animals, safeguarding their health and welfare, and finally utilizing their products.

Shows Opportunities for Further Progress

Within the same period great improvement in breeds and types has likewise occurred. Records of production

THE IMPROVEMENT OF POULTRY.

POULTRY, AS WELL AS THE LARGER FARM ANIMALS, ARE BEING IMPROVED BY SELECTIVE BREEDING COMBINED WITH SCIENTIFIC METHODS OF FEEDING, CARE AND HOUSING.

by individual animals have steadily increased. It is not unusual for dairy cows to produce more than 20,000 pounds of milk annually, for a litter of pigs to weigh more than a ton at six months of age, or for a well-bred hen to lay more than 250 eggs in a year All these figures greatly exceed ordinary performance and point to goals that are readily accessible by the means that modern knowledge has made available.

Though we have cause to be grateful for the contributions of research to our welfare, a true appraisal of science in the live-stock industry shows, however, that Nature is still our greatest benefactor. No investigator has thus far evolved a fully satisfactory substitute for meat, milk, leather, eggs, and scores of other animal products. And the abundance of these products in daily use indicates preference for them to many articles resulting from purely artificial processes. Thus we are richly endowed by having, in the animal resources at our disposal, a plastic living material that we can adapt to our changing needs

Formerly, in the wild state, animals were both a source of danger to mankind and a somewhat uncertain resource. But under domestication and with the increasing knowledge that science has provided, the lower animals have become one of the most valuable assets of our civilization

LEPROSY IN THE UNITED STATES

By Dr. WILLIAM W. FORD

PROFESSOR OF BACTERIOLOGY, SCHOOL OF HYGIENE AND PUBLIC HEALTH, JOHNS HOPKINS UNIVERSITY

THE history of leprosy has always been of peculiar interest to members of the medical profession because of the important problems which have arisen in regard to its causation and mode of spread. No less interesting has it appeared to the non-medical, since references to it abound in Biblical and secular literature and many an individual, doctor, nurse, priest or pastor has devoted years of self-sacrificing effort to the care of the unfortunate lepers, in spite of the hardships which had to be endured and in the face of a possible transmission of the infection from the victims of the disease. Religious orders of nearly every denomination have been active especially in their care, and in many regions it has been to the inspired members of these orders that the lepers have looked for attention during life and for spiritual consolation in their closing hours. The life and death of Father Damien, the Belgian Catholic priest who went to the leper colony in Molokai and who eventually contracted the disease and died from it, have been immortalized by Robert Louis Stevenson.[1] Books of travel and romantic literature are full of references to leprosy. In Richard Burton's "Ultima Thule," which is an account of his visit to Iceland in 1872, there is an excellent description of the disease, and the picture of leprosy given by Lew Wallace in "Ben Hur" has aroused the compassion of countless readers. Of especial interest is the extent to which lepers and dramatic incidents connected with them have been depicted by great artists of the past. One need mention only Donzello's "Saint Martin" in the National Museum in Naples, the "Job with Wife and Friends," by Lucas Cranach, or by an artist of the Cranach School in Frankfürt a.M., the "Job," by Albrecht Dürer in Frankfürt a.M., the "Saint Elisabeth with a Leper," by Holbein in Basel, and the "Saint Elisabeth," by Murillo in Madrid, to indicate how frequently lepers appear in the great canvases of the old masters.

Modern knowledge of disease, and especially the study of the origin and spread of the type which is called contagious or communicable, has taught us much about leprosy and we now realize that many of the ideas formerly entertained in regard to it were erroneous. We know that leprosy is not violently contagious, does not pass rapidly or easily from person to person, apparently requires a long period of exposure and that its spread in a community is determined by many factors in addition to the presence of a leper. Yet the fear of leprosy which has come down to us through the passing of 2,000 years and more is still entertained by many and at times stimulates a cruelty and persecution which are reminiscent of the Dark Ages.

Leprosy, also called *Leontiasis, Satyriasis, Elephantiasis Graecorum, Lepra Arabum, Aussatz* in German and *Spedalsked* in Norwegian, has been known from early times. It is now believed that the word "leprosy" as used in the Biblical sense was a generic term covering various sorts of skin disorders which rendered the afflicted individuals "unclean" and disqualified them for the worship of Jehovah. The descrip-

[1] Robert Louis Stevenson, "Father Damien: An Open Letter to the Reverend Dr. Hyde of Honolulu."

tion found in very early Japanese medical writings probably refers to another ailment, but the disease now regarded as leprosy was apparently recognized in China in the twelfth century before Christ. The leper "whiter than snow," however, was not a victim of leprosy but rather of a totally distinct skin disease now called leucoderma. While the ultimate origin of the disease is masked in impenetrable obscurity, satisfactory accounts of it were given by Aretaeus in the first century of the Christian Era and in the second century Galen described it from the cases he saw in France and Spain. It was known in Egypt and India, as well as in China, long before the Christian Era and was wide-spread in all the countries about the Mediterranean Sea. Carried westward by the Roman soldiers and traders when the power of Rome was at its height and later disseminated by the Crusaders, it spread throughout Europe and became a scourge in the Middle Ages, reaching France, Germany, England, Ireland, Scotland, the Scandinavian Peninsula and many of the outlying islands of the North Sea. Gradually the disease came under control, probably in large part as a result of the strict isolation of the afflicted, an isolation which we now regard as cruel and unnecessary. With a practice based on the Mosaic laws as laid down in the book of Leviticus the lepers were driven away from families and friends, forced to live in out-of-way, desolate places, to subsist largely on charity, their food and clothing procured by stealth, and compelled to announce their presence by crying "Unclean," shaking a rattle, ringing a bell or blowing a horn. Indeed in some particulars their persecution went far beyond this, for sometimes their property was confiscated by the state, when they were people of means, and usually the civil authorities cut them off from human society when the disease was discovered by medical inspection (Lepraschau), so that they were legally dead from that time on. But it must be remembered that these cruelties were perpetrated in a cruel age when capital criminals were hanged, drawn and quartered, when political crimes were expatiated by breaking on the wheel, when men, women and even children were burned in frenzies of religious zeal, and when petty malefactors were stretched and jerked upon the scaffold so that the joints of the long bones were dislocated and they became hopeless cripples. One likes to think rather of the consideration and kindness with which lepers were treated in the period of awakening enlightenment at the end of the Dark Ages when, after the example of Basil the Great at Caesarea, over 20,000 leper homes were established in Europe and where the leper was at least sure of food, lodging and a place in which to die.

As a result of the stringent regulations and the segregation practiced in Europe during the Middle Ages, the number of cases diminished with considerable rapidity and the disease died down except for isolated instances appearing from time to time over a wide area. It persisted in several places which are of interest to America, for foci of leprosy remained in Brittany and Normandy, in the Scandinavian Peninsula, particularly in Norway, and in Iceland. In the south, leprosy was common on the West Coast of Africa where it is still prevalent, as well as on the East Coast.

In the area now embraced in the United States leprosy appeared quite early in several regions. It was reported in Louisiana in 1784 and is said to have been brought by Spanish settlers. It got a foothold, however, among the families of French origin who came from a part of France where leprosy was endemic. Ever since that time the disease has been found in

Louisiana and has been in general limited to French families. In 1900 there were 125 reported cases, but since then the number has decreased gradually but definitely. It has shown little tendency to spread to other elements of the population. The lepers were originally cared for in their homes or admitted to some of the hospitals in New Orleans. Eventually the state established a leprosarium at Carville. With the settlement of Minnesota, leprosy was introduced by the colonists from Scandinavia, chiefly by the Norwegians coming from a country where the disease was endemic. The lepers were in general isolated and looked after by their families, but the facilities for their care and treatment were so inadequate and the lot of the unfortunate leper so unhappy that Dr. Bracken, state health officer, came to their aid and by his courageous example did much to allay the popular fear of the disease. Through Dr. Bracken and other health officers interested in leprosy the United States government was induced to take over the Louisiana State Leprosarium, which thus became a National Leprosarium. Thirty years ago there were about 50 reported cases in Minnesota. Since then the disease has constantly diminished in frequency, partly of course because many of the lepers are transferred to Carville. At the present time there is but one active case in Minnesota, cared for with strict isolation under the state department of health. In Minnesota leprosy has shown no tendency to spread from the colonists who brought the infection with them to other elements of the population, and the state can now be said to be free of the disease.

In Canada the history of leprosy is especially interesting, but the facts in regard to it are somewhat difficult to establish. Foci have existed from early times among the Acadians in Nova Scotia and New Brunswick, among the French Canadians in New Brunswick and in a few spots elsewhere. Many conflicting stories about its origin in Canada have been current from time to time, sometimes to the effect that the disease was carried by the Acadians to Louisiana after their expulsion from Nova Scotia in 1755 and again that leprosy was contracted by the Acadian families during their sojourn in Louisiana and taken back by them to Nova Scotia. The origin of leprosy in Canada has recently been investigated with care by Dr. John H. Heagerty, of the Canadian Department of Health.[2] He states that it first appeared in official records as found in Tracadie in the Province of New Brunswick in the year 1815, in a French Canadian family coming originally from Normandy, in which it was introduced by leprous Norwegian sailors. This story has been denied and Heagerty points out that there is some evidence to show that leprosy was present from early times in the district known as Acadia, which comprised Nova Scotia and a part of New Brunswick, including Tracadie. A lazaretto was established at Tracadie in 1815 and from that time till 1924 319 lepers were admitted, chiefly from New Brunswick and Nova Scotia. In Canada again, the disease has tended to limit itself to well-defined groups of people, but has appeared among families of Scotch, English and Irish descent, as well as among those of French origin. At the present time, the leprosarium supported by the Dominion of Canada at Tracadie, New Brunswick, on the Gulf of St. Lawrence, houses 10 lepers, of whom 4 are French Canadians, 3 Russians, 1 French-Scotch, 1 English and 1 Chinese.[3] Leprosy in eastern parts of Canada is thus reduced

[2] John J. Heagerty, "Four Centuries of Medical History in Canada."

[3] Personal communication from Dr. Norman M. Harris, of the Department of Pensions and National Health, Dominion of Canada.

to a small number of cases and the disease is gradually disappearing.

Finally, both in the United States and in Canada, cases of leprosy have been somewhat frequent among the Chinese resident in the cities along the Pacific Coast such as San Francisco and Vancouver. The cases occurring in the United States are now sent to Carville, while the Dominion of Canada maintains a small leprosarium at Bentinck Island, British Columbia, within three miles of the quarantine station at William Head. This leprosarium now harbors nine Chinese lepers and is maintained primarily for this group, those of other nationalities being sent to Tracadie.

In addition to these well-marked foci of leprosy in North America, sporadic cases occur from time to time, chiefly among inhabitants of Louisiana, Florida, Texas and Mississippi, where the disease may still be regarded as endemic. Occasionally cases appear in other states such as Massachusetts,[4] New York, California, Missouri, New Jersey and Maryland. In these areas the advanced cases are now sent to Carville, while the non-infectious are cared for by state or city departments of health.

From this brief review two facts are quite clear. One is that leprosy is definitely decreasing in the United States and Canada. The other is that it presents no menace to this country. Both in Canada and in the United States, the cases are recognized early, advanced cases are sent to suitable institutions, and the disease shows no tendency to spread out of well-defined areas. Leprosy then can not be regarded as a public health problem of any importance in these countries. To the south of us, in Mexico, the condition is not so favorable, since cases of leprosy are fairly frequent, especially in Mexico City. This affects the United States only when Mexican laborers in this country develop the disease, in which event they are either sent back to their homes or committed to the national leprosarium.

At the present time the United States government twice a year gathers the lepers found on the Pacific Coast in special trains and transfers them to Carville. From 1894 to 1928, 718 have been admitted to Carville and 300 cases are now under treatment there.

With the acquisition of the Hawaiian Islands (Sandwich Islands) and the Philippines in 1898 the problem of this disease took on a somewhat different aspect for our government. In the Hawaiian Islands, a population of about 100,000, with a large amount of leprosy, was added to our numbers. Here the disease was introduced about the middle of the nineteenth century, apparently by the Chinese. The infection spread rapidly among the Hawaiians and reached such alarming proportions that the native government, in 1864, established a leper settlement at Molokai,[5] the administrative control of which was assumed in a general way by the United States with the annexation of the Islands. The number of new cases in Hawaii has varied greatly from year to year, reaching 558 in 1888 and falling to 23 in 1908. The average yearly number is now about 50, and the disease has been found chiefly among the people of native blood. In 1890, 1,230 lepers were in isolation. Since then the number has decreased considerably and in 1928 had fallen to about 700.

In 1898, when the Philippine Islands were taken over by the United States, we acquired a new population of 7,000,-

[4] Massachusetts formerly maintained a state leper colony on Penikese Island, where a few cases were segregated. In 1922 this station was given up, the active cases being transferred to Carville.

[5] See "The Public Health Aspect of Leprosy," by Dr. George W. McCoy, *Boston Medical and Surgical Journal*, 1917, Vol. 126, No. 2, pp. 43–48.

000, now increased to about 13,000,000. Leprosy is a common disease among the inhabitants of these islands. It is said to have been brought to the Philippines by a boat-load of 150 lepers sent there by the Japanese about 1750, but it must be remembered that leprosy was still endemic in Spain at that time and that Spanish colonists may well have carried the disease to the Philippines, just as they probably did to large areas of South America, Central America and Mexico. At any rate leprosy spread rapidly among the native Filipinos and soon became one of the prevalent ailments. It is estimated that there are no less than 200,000 lepers in the Islands at the present time, spread among all the native tribes, among the Japanese and Chinese. A detention service is maintained in Manila in the San Lazaro Hospital, but the majority of the lepers are sent to a leper colony at Culion Island, a remote spot where between 5,000 and 6,000 cases are now housed and treated. Other hospitals on the island look after a great many in addition. Recently, under the Manila Board of Health and Leonard Wood Memorial Association, treatment stations for leprosy have been established at various points and a determined effort is being made to combat this scourge. Research is fostered, experts are trained, and correct information spread throughout the land.

Finally a word or two may be said about the purely medical aspects of leprosy. It is in general one of the saddest of human spectacles, chiefly because of the outspoken aspect of the lesions, but partly from the hopeless character of the infection. It appears in two main forms, the *nodular type,* in which nodules develop beneath the skin in various parts of the body, and a *macular-anesthetic* type, in which eruptions occur on the surface and in which extensive areas are rendered *anesthetic* with loss of sensation. The nodules may become large and deforming, the face may become so changed that resemblance to the human facies is almost lost, the swellings may break down and ulcerate, giving rise to foul, ill-smelling masses. The eyes are affected and sight is frequently lost. Ulcerations occur in the nose and mouth, and the larynx may be involved, causing extreme shortness of breath. The anesthetized parts are so easily injured that fingers and toes may actually slough off almost without the knowledge of the patient. Altogether the advanced leper may present about the most horrible of human monstrosities. The disease is essentially chronic, and the period from the outbreak of symptoms to the fatal termination may last for years. This chronicity of leprosy, with the prolonged period of contact necessary for transmission, its long incubation period, its slow development from the period of recognizable lesions to its eventual termination and the leisurely spread in the population is well pictured by Sudhoff,[6] formerly professor of the history of medicine in Leipzig. From the early days of bacteriology investigations on the cause of the infection have been carried out in various parts of the world. There can be little doubt that the etiological agent is an organism described as the leprosy bacillus by Hansen in 1880. This organism closely resembles the tubercle bacillus, the cause of tuberculosis, but it has never been definitely cultivated outside the body on artificial media. Nor has leprosy ever been transmitted to the lower animals. The presence of the leprosy bacillus is diagnostic of the disease, however, and is our chief means of assured recognition. Leprosy is transmissible from person to person and never appears spontaneously in a community free from it. Prolonged contact with a case seems to be necessary

[6] Karl Sudhoff, "Epidemiological Rules of the Past," in "Essays in the History of Medicine," translated and edited by F. H. Garrison.

to transmit the infection, the kind of contact which comes from living in the same house, eating from the same utensils, washing the clothing of lepers over long periods. The disease is not hereditary, and children of leprous parents, removed from them immediately after birth, do not develop the infection. The incubation period, that is, the time between exposure and the outbreak of definite signs of the disease, is long and subject to great variations. It may be as short as two years and as long as ten years. Various factors seem to play a rôle in the propagation of leprosy, that is, in the origin of epidemics, and these factors are by no means clearly understood. At times it seems to spread in family stocks. Thus Hopkins and Denny,[7] in their careful study of leprosy in the national leprosarium at Carville, have pointed out a distinct familial tendency in Louisiana, in that leprosy appears in closely related families. Again it seems to spread in racial stocks, as in the Hawaiian Islanders, but McCoy believes that this is not necessarily a racial tendency but may result from habits of living or other factors. Climate has been thought to influence leprosy, but it may become epidemic and remain endemic both in the tropics and in cold countries like Scandinavia and Iceland. It is doubtful whether food is a factor, although years ago Jonathan Hutchinson pointed out that leprosy was apt to occur in people who subsist largely on fish. At the present time we can say that leprosy spreads and remains endemic in certain countries like China, Japan, the Philippines, the Hawaiian Islands, and dies out in Northern Europe and in North America. Certainly in the United States and in Canada leprosy does not survive under modern conditions and is slowly but definitely disappearing.

The most hopeful thing about leprosy at present is our changed attitude in regard to the treatment of lepers. It has now been demonstrated that, in institutions where the disease can be treated by approved medical and surgical measures, the course of the infection can be arrested in many individuals and the lot of the others be made immensely happier. From rest in bed, outdoor life, abundant food, a regimen not unlike that practical in tuberculosis, some cases improve steadily and the infection becomes quiescent. Modern surgery can accomplish much. "Disfiguring nodules may be excised, necrosed bones removed, necrotic extremities amputated, and by tracheotomy permanent relief afforded for the laryngeal stenosis so common among the unfortunates" (McCoy). Probably the most important contribution to modern therapy is the use of the drug known as chaulmoogra oil or its derivatives. In many instances this drug can accomplish in a short time what general measures may effect only in months and years. It has been employed on a large scale in the Philippine Islands and especially in Manila, where the board of health has for some years treated leprosy with various derivatives of the crude oil. Recently the Leonard Wood Association has extended the use of chaulmoogra oil with gratifying results and has aroused our hopes for the future. While leprosy will not disappear from the world for long periods, if at all, the disease has passed into the category of ailments which can be helped by modern methods of medicine and surgery, and to a considerable extent be prevented from spreading.

[7] Hopkins and Denny, "Leprosy in the United States." Reprint No. 1274, from the Public Health Reports of the United States Public Health Service, Vol. 44, No. 13, March 29, 1929.

THE HAZARD OF THE AUTOMOBILE

By Dr. JAMES A. TOBEY

NEW YORK, N. Y.

In spite of rigid traffic regulations, constant educational campaigns to promote highway safety, and many other efforts, the mortality from automobile accidents is increasing at an alarming rate in the United States. Automobile accidents now result in about five times as many deaths in this country as does typhoid fever, once a widely prevalent scourge. Such accidental deaths have now reached the unenviable position held by this malady in 1910. Due to the efforts of sanitary science, typhoid fever is a vanishing disease, especially in our cities, and its death-rate in 1929 was about as low as was that from automobiles some twenty years ago. There are now, in fact, only about ten diseases which cause more deaths than do automobile accidents.

Measles, whooping cough, scarlet fever and diphtheria combined do not take any greater toll to-day than does the automobile. There are as many fatalities from automobiles as there are from homicides and suicides together, and there are more deaths from this cause than from either diabetes or appendicitis, and about as many as from diseases of the arteries. Heart disease is now the leading cause of death in this country, but even this affliction has only about seven times as many victims as the automobile. For every four deaths from cancer, there is one due to the automobile. As an instrument of slaughter, the mechanical carriage ranks unduly high.

The situation is undeniably serious and, unlike the mortality from most other preventable causes, is getting worse. Twenty years ago the automobile, then somewhat more rare as a possible agent of destruction, was a negligible factor in the mortality tables, but to-day it is responsible for more than 2 per cent. of the total of almost a million and a half deaths which occur annually in the United States. If the present rate of increase continues, as it has for the past decade or more, automobile accidents will eventually be at or near the head of the list. The facts call for immediate attention and urgent action, in addition to the many attempts now being made to cope with the situation.

Nearly a million persons suffered more or less disabling injuries in automobile accidents in 1929 and a definite increase has been recorded for 1930. In 1929 there were more than 31,500 deaths, a rate 13 per cent. higher than in the previous year, although the number of cars registered increased only 8 per cent. There are now about 27 million motor vehicles to infest the highways, and any tourist will tell you that most of them seem to be in action every Sunday. It is estimated that there are 700,000 cars in New York City alone, and another 900,000 in the metropolitan area. In 1910 there were less than 30,000 in this same city. Not only is the death rate from automobile accidents rising in the general population, but it is increasing per 100,000 cars. From 1918 to 1926 the number of accident per car declined, but since that time it has been steadily augmented each year.

Since 1910 the mortality from automobile accidents has gone up almost 1,000 per cent. The rate for the country as a whole ir 1928 was 20.8 deaths per 100,000 population, though in many states it was much greater. California had the worst record, with a rate of 38.5, according to the figures of the United States Bureau of the Census. Delaware was second, with 30.7 and

Florida third, with a rate of 28.6, which was, however, slightly lower than in 1927. The states with the two largest cities, New York and Illinois, had rates above the United States as a whole, but not excessive in comparison with some other commonwealths, though much higher than was proper or creditable. The New York rate was 22.1 per 100,000, while that in Illinois was 23.6.

In all the states except eight there were increases in automobile accidents in 1928 over 1927, and there were still further increases in 1929. The lowest rate in 1928, according to the latest available data, was in Arkansas, but its figure of 10.9 showed a considerable increase over the 8.8 of the preceding year. In the Hawaiian Islands the rate went up from 16.7 to 26.0 in that one year.

This growing menace from the motor vehicle has not been checked in 1930, as the data from the Bureau of Census for 78 large cities showed 655 deaths from automobile accidents during the four weeks ended January 25 of this year, whereas there were 612 deaths in the corresponding period of the year before. The rate has increased just 11 per cent. in the first month of the current year. For the 52 weeks ended March 22, 1930, the rate was even higher. It represented, in fact, an increase of 147 per cent. over the mortality for 1920. Later records are similarly appalling.

Motor fatalities are no more prevalent in urban areas than in rural. In New York State an investigation of these accidents in 1927 revealed that the death rate outside of New York City was higher than in that metropolis, being 26.6 per 100,000 for upstate, 18.3 for New York City, and 22.3 for the state as a whole. After allocating the deaths to the locality where the accidents occurred and not where the deaths took place, it was discovered that the rate for rural New York was 39.3, as against 19.4 for urban New York, or some 51 per cent. higher among the drivers in the open country.

These unreasonably numerous automobile deaths affect every age and class of our population. Children under fifteen years of age are the unfortunate victims in from 35 to 40 per cent. of all these casualties. Dr. Ray Lyman Wilbur, Secretary of the Interior, was right when he stated recently that a rattlesnake is a domestic pet compared with the automobile. "Rattlesnakes," says Dr. Wilbur, "kill about a thousand persons a year in the United States, but approximately a hundred thousand children will be killed or maimed by automobiles within the next twelve months. We take the automobile for granted because it is useful, but this usefulness comes to us at great cost."

What is the reason for all this carnage by the modern automobile? The answer lies, of course, in the human element concerned. The careless, the arrogant, the unfit, the unbalanced and the drunken driver are at fault in most instances. Congestion of traffic, better roadways offering opportunities for speeding, lax licensing requirements, and possibly greater mental and emotional instability, due to the complexities of modern life, are all factors. It has been estimated that at least 10 per cent. of all automobile drivers are unfit to handle such a complicated mechanism as a moving motor vehicle. Probably the estimate is conservative.

Statistics from eleven states having nearly one third of the total automobile registration of the country, which were collected recently by the Travelers Insurance Company, revealed that the licenses or registrations of 77,704 motorists were suspended or revoked out of a total of 7,178,111 registrants. Driving while under the influence of liquor, excessive speed and failure to report an accident were the principal reasons for these revocations, though in three states all or most of them were the result of an

attempt to mix intoxicants with driving ability, or inability.

Many persons are physically or mentally incapable of being skilful drivers of automobiles, even if they do operate cars. Others may have been competent when their licenses were first issued, but have since become incompetent because of age or some acquired physical handicap. A considerable proportion of the automobile accidents are, in fact, caused by experienced drivers, or at least by persons who have had licenses for a number of years. Few, if any, states have re-examinations, and none requires a complete physical and psychiatric examination of an applicant. At the annual meeting of the American Medical Association in Detroit last June, a report was adopted urging that all drivers of motor vehicles ought to have physical examinations by reputable physicians, so that vision and other important items could be checked up.

European requirements regarding the fitness of automotive drivers are more stringent than in the United States. In sixteen European countries, Germany, Bulgaria, Denmark, Danzig, Esthonia, France, Great Britain, Holland, Hungary, Latvia, Luxembourg, Norway, Poland, Sweden, Switzerland and Jugoslavia, a medical examination of all prospective drivers is compulsory, according to the results of an investigation made in 1928 by a Belgian scientist, Professor Weekers, for the *Association Professionelle Internationale des Medecines.* In France and Great Britain, such examinations must be made only of drivers of public vehicles, but in other countries they apply to all drivers, and in some instances they must be repeated at regular intervals, sometimes one, two or five years. How meticulously the requirements are enforced does not appear from the study.

A clinical study of 100 traffic offenders brought before the Recorder's Court in Detroit resulted in the startling revelation that one of the violators was psychotic, or insane, 12 were definitely feebleminded, and 42 had inferior intelligence. Of the whole lot, only 13 were given a clean bill of health as safe and reliable drivers, though 97 of the 100 had officially issued licenses. Nearly one half of the subjects before this clinic for drivers were seriously handicapped by alcoholism. Such operators as these not only have accidents themselves, but cause trouble to others.

That there is some glimmer of hope in the present American situation with respect to the holocaust of automobile fatalities is indicated by a recent investigation made by the Metropolitan Life Insurance Company of New York. Although deaths from this cause were increased in the aggregate in 1929, there were 24 cities which actually displayed a decrease. An inquiry was sent to the appropriate official in each of these outstanding cities, and 15 were courteous enough to reply. The most conspicuous activity in every one of these municipalities was a campaign of safety education in the schools, although due attention was also given to effective traffic control.

Education in the principles of safety for drivers and pedestrians, plus strict enforcement of reasonable licensing requirements and inspection of automobile equipment, seems to offer a solution to this problem. More courteous road conduct, the curbing of reckless driving, especially when the motor vehicle operator has been plied with poor liquor, and attention to the mechanical condition of the car will do much to reduce the many unnecessary and preventable accidents which are now accounting for too many postponable deaths and avoidable injuries. Complete medical examinations for all drivers and rigorous exclusion of the unfit is undeniably a step that will have to be taken sooner or later.

WHAT THE FOOD AND DRUG ADMINISTRATION DOES

By T. SWANN HARDING

MT. RAINIER, MARYLAND

THE food and drug law, passed in 1906, had two major purposes. It was designed first to safeguard the purity of food and drug products and, secondly, to enable consumers to avoid economic fraud. It was intended then to protect the health and the pocketbooks of the public and this purpose was to be accomplished by keeping package labels, and the advertising matter distributed with food and drug packages, absolutely truthful. Enforcement was first vested in the Bureau of Chemistry. This bureau was composed of both research and regulatory units and, by July 1, 1927, it was discovered that greater efficiency would result if these were separated. The Bureau of Chemistry and Soils was then organized as an administrative unit designed to undertake research work and the Food, Drug and Insecticide Administration (the word "Insecticide" was dropped on July 1, 1930) came into being to enforce the food and drug law and five other similar acts relating to tea, caustic poisons, import milk, insecticides and fungicides, and naval stores, such as turpentine, etc. Precisely the same officials had charge of the enforcement of this law as before; they could merely work more efficiently. Furthermore, exactly the same regulations were followed by them in law enforcement as had served the old Bureau of Chemistry. This much should be said to avoid all initial misunderstandings.

The law is not perfectly enforced. No law is. This particular law costs us but a penny per caput in the matter of enforcement and only 530 employees, but half of whom are technicians, are hired for the enforcement of all six laws administered by the Food and Drug Administration. Furthermore it is rather ridiculous anyway that the law should have jurisdiction over package labels and over the statements made in printed matter accompanying packages, whereas it is without authority to control statements made by manufacturers regarding the very same products in newspaper and magazine advertising, over the radio or on billboards. That leaves a large loophole for faulty enforcement and requires officials to concentrate on read-the-label propaganda when what is really needed is to have all advertising statements honest wherever they appear. Finally, we can see that it is obviously impossible for so small a force spending so little money to run down every violation of the law. When we further consider that 22 labored steps are required from the time goods are seized until a case is closed, and when we remember the crowded condition of the courts, we can see plenty of reason for the exercise of considerable ingenuity to arrive at efficient enforcement of the law under the circumstances. It is also plain that the law needs strengthening, whereas to-day powerful economic forces seem determined to emasculate and further weaken it if possible.

Nevertheless the food and drug law is better enforced to-day than ever. This may be charged to a variety of factors. In the old days under the Bureau of Chemistry every case stood by itself. Inspectors were accountable to a central authority rather than to the chiefs of branch laboratories which were then, as now, conveniently located. Seizures were made irrationally and hit or miss.

Even if a case was finally won it stood entirely alone and unrelated to the work on other cases by the same bureau. Today, all that is changed. The eighteen branch laboratories of the administration have been organized into an Eastern, a Central and a Western district with headquarters in New York, Chicago and San Francisco. Chiefs of branch laboratories are really chiefs, and both inspectors and chemists are accountable to them. Campaigns of procedure are carefully planned in advance and followed rigorously, although they are always sufficiently elastic to permit a special assault when conditions necessitate, as in the most recent influenza epidemic when a variety of fraudulently labeled remedies suddenly sprung up and demanded action. The establishments of manufacturers are themselves examined and reports made to district headquarters. In case of questionable factory processing, shipments of the goods produced are followed into other states and inspectors on duty there make seizures rationally and with some reason to expect fraud. No case stands alone, but takes its place in an orderly plan. Educational and corrective means are used wherever possible, both because it has been found that they will give the public greater protection, if less noise and excitement, than jail sentences, and also because it appears that 95 per cent. of our manufacturers are quite ready to cooperate with the government in complying with the law once they understand what is desired.

To give a complete picture of this law enforcement work in the brief space allotted is impossible. We must therefore narrow the subject and use certain specific types of remedies and the campaigns against them as illustrations to show how the administration proceeds with its work and what protection it offers the American public against quackeries and falsely advertised remedies. We shall not consider foods but limit ourselves to the drug products which in recent years have fraudulently purported to do the impossible. Thus in June, 1929, a report was made on a special campaign waged against rheumatism "cures" during which action was taken against 245 such products. In fact rheumatism cures have, for some reason, led the list of fake remedies against which the Food and Drug Administration has recently had to take action. The evils of self-diagnosis are quite apparent here, for more aches and pains are carelessly regarded as "rheumatism" by laymen whereas they may be symptoms of fundamental disorders —local infections, tuberculosis, venereal disease—which need prompt specific treatment. Again, while laymen commonly regard gout and arthritis deformans as rheumatism, they are not that at all. In fact the trouble may be nothing more formidable than fallen arches. Certainly no one form of treatment could possibly remedy all these varied aches and pains and even more certainly products composed of simple plant extractives, red pepper, turpentine and impotent mineral salts—common ingredients of rheumatism "cures" —could be expected to accomplish little therapeutically.

Mention of rheumatism brings to mind the fact that many of the remedies for this disease, which so far completely baffles medical science, played upon popular knowledge of and respect for what are supposed to be radioactive substances. Hundreds of such preparations were examined by the administration in a recent campaign and less than 5 per cent. of them contained any radioactive substance at all; these usually contained such material in quantities entirely too small to have any physiological effect— so small in many cases indeed that the patient would have to drink several gallons of the concoction daily to produce an effect. These products came in various forms; some were to be steeped in water, others to be hung over the bed

in small bulbs. An active product of this kind would be an exceedingly dangerous thing for a layman to use and it is perhaps fortunate, in a way, that so many of them were frauds of an impotent character. This particular type of trickery has been pretty well cleaned out for the present, but it must always be remembered that new frauds can come into existence with almost incredible rapidity.

In this connection one of the difficulties the administration faces might be emphasized. In the case of court action the case has to be so clearly presented that a jury of laymen will somehow comprehend the technical points involved and act in accordance with the scientific evidence presented. But suppose a remedy, like Gowan's Pneumonia *Cure* of early days, is suppressed, as this one was by Notice of Judgment No. 180. It can become, as this one did, Gowan's Pneumonia *Remedy* and is then ready to face a further fight. Ultimately it became merely Gowan's Pneumonia *Prescription*. It later appeared in 1928 as Gowan's *Preparation* and was then an application recommended for pneumonia, pleurisy, croup, colds, coughs, throat troubles, soreness, rheumatism, congestion and inflammation. It was an external ointment composed of phenol, menthol, camphor, turpentine and quinine sulfate, certainly incapable of acting remedially against many of the pathological conditions named on the label. These claims were restricted, but in 1929 a new manufacturer had bought the famous preparation and, while the label recommended it only for colds, burns, bruises, sprains, sunburn and insect bites, it was advertised in the press as useful to avoid influenza, coughs, croup, bronchitis, etc., conditions which the label no longer listed. This illustrates two things: first, that a product can change its form and its claims quickly and frequently, and thus require continual watching while acquiring temporary immunity; secondly, that after its package label is scientifically correct, it can make impossible claims in newspaper and magazine advertising which, being outside the scope of the Food and Drug Act, can not be prohibited.

During the influenza epidemic new remedies flooded the market and well-known preparations began to make unwarranted curative claims. Zonite, for instance, advertised itself in the press as "striking directly at influenza" if it were evaporated in a flat dish on a radiator; it recommended itself likewise for dandruff, wounds, ulcerations, pimples, boils, eruptions, sinus trouble, sore throat, etc. It is a solution of sodium hypochlorite yielding approximately 1 per cent. of available chlorine. Notice of Judgment No. 16217 issued September, 1929, declared its more comprehensive claims false and fraudulent. Nozol, which consisted of a heavy petroleum oil containing menthol, camphor and a red dye, claimed to be "unequaled in cases of Catarrh, Hay Fever, Asthma and General Nose Troubles" and to relieve sinus trouble; in the press it offered sure protection against flu. Notice of Judgment No. 16221 issued September, 1929, declared its label claims false and fraudulent. In a press release issued earlier this year the administration said:

> Reports on some 800 preparations sold as cures or preventatives of influenza, grippe, or pneumonia have been sent in to the Food, Drug, and Insecticide Administration from the field since the first of the year, when an intensive campaign against falsely labeled products of this type was launched. These reports, giving the results of factory inspections and examinations made by the field stations, in conjunction with the labeling accompanying the packages in interstate commerce, have served as the basis for the procedure adopted by the administration for driving from the channels of trade so-called remedies for which promises that can not be fulfilled are made.
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> The consensus of present-day reliable medical opinion is that no competent drug treatment exists for influenza, grippe, or pneumo-

nia. Nevertheless, as shown by this campaign, many makers of proprietary remedies came forward during the recent "flu" epidemic with products represented as certain cures, but which were totally unreliable, thus hoodwinking the public, a large fraction of which is gullible when its health is concerned, into a false feeling of security and forcing unfair competition upon vendors of truthfully labeled articles. . . .

The labels of many preparations are in perfect compliance with the law, making no therapeutic claim that might not reasonably be expected to be met by a combination of the ingredients used, but the advertisements for these same preparations spread flamboyantly over whole pages of magazines, trade journals, and newspapers, and broadcast by radio, show much less restraint. Many of these advertisements do not hesitate to state unqualifiedly that the products in question can prevent or cure influenza, grippe, pneumonia and certain other diseases. This kind of misrepresentation can not be reached under the Federal food and drugs act as it now stands.

The administration has also taken action against numerous antiseptics recently. It is a curious fact that many manufacturers had never had their products tested in order to see whether they actually were capable of destroying bacteria; many of them believed that a substance, like carbolic acid, would be antiseptic in no matter what dilution it was used. In many other cases it was a question of time of contact: if the reputed antiseptic could be permitted to remain in contact with the infected surface sufficiently long antiseptic action might take place. But the time required for some mouth washes, for instance, would be fifteen minutes, whereas such preparations are usually rinsed about in the mouth and almost immediately expectorated. On the other hand, if a product were made sufficiently powerful in its antiseptic agent to act antiseptically in the time claimed it would be exceedingly likely to take the tissues of the mouth along with it when expelled. A general cleanup of the antiseptics followed and their labels were rendered truthful.

One widely advertised preparation might be mentioned which advertised in the press that there were 80 square inches of tissue in the mouth where the germs causing 30 diseases originate. Bacterial decay was said to start here in a food film which existed throughout and most other antiseptics would merely mask the odors accompanying this process. But this new antiseptic cleaned the mouth, killed the bacteria, and removed all decay and all odor thereof. What were the facts? Of the 30 diseases listed —and bronchitis, croup, diphtheria, leprosy, typhoid fever, parotitis, influenza and scarlet fever were among them—only *one* can be traced to the mouth area which contains more nearly 50 than 80 square inches. The mouth parts do not extend from the lips to the first rib as pictured in the advertising. There is no wide-spread food film therein at any time to decay at 90° F. The alkaline saliva counteracts the poisonous quality of the small amounts of decaying food which can collect, and, kept in the mouth the brief period recommended, the antiseptic would do little or nothing. In short the product was just another mouth wash of pleasing taste and of little or no therapeutic or germ-destroying value.

A final word might well be said about antifat "cures." In proceeding against these the Food and Drug Administration labors under the slight limitation that obesity can not clearly be shown to be a disease. Unless a drug product makes false claims to remedy disease it is a little hard to proceed against it and antifat remedies, like superfluous hair removers, tend to stand with cosmetics rather than drugs. The superstition is old that soap and water are bad for the face; it arose when soaps really contained considerable free alkali and often did injure many delicate faces. To-day it stands cosmetic manufacturers in good stead and they continually add to

their lines all sorts of auxiliary preparations, including antifat remedies.

For this reason the following words by Dr. F. F. Cullen, of the Food and Drug Administration, are not without interest:

Promoters of so-called obesity remedies and fat reducing cures are attempting to influence fat people to spend money for worthless or dangerous preparations. The advertisements appeal to the vanity of persons who wish to regain slim, graceful figures and also to the business necessities of those who become so fat that they can no longer do their work efficiently. The principal appeal of most of the promotion claims is that no dieting is necessary; the medicine is to do it all and the advertiser says the patient can eat all he wants and as often as he wishes, which is a strong inducement to most stout people.

These preparations frequently contain thyroid and laxatives. The promiscuous use of thyroid may prove very harmful unless given under the advice of a physician personally familiar with the subject's physical condition. The department has on record an instance where death has followed an overdose of a preparation containing thyroid. Some preparations contain poke root (phytolacca), a poisonous drug, and others, analysis shows, contain nothing that could possibly have the slightest effect in reducing flesh.

The promoters of one preparation assert that it secures most marvelous results by a process of elimination of foods without digestion. These people guarantee the reduction of a pound a day. A preparation of this character, if it did what its makers claim for it, would probably eliminate any need of digestion in the future. Another product, examination shows, consists principally of ordinary soap. The idea is to apply this locally with friction and thus remove the fat wherever it may be in excess. A still more clever scheme provides chemicals to be added to the water in which the patient is to bathe. These chemicals are of such a nature that they form a sort of curd in the water after the patient has bathed. This curd, the advertisement states, is fat and surplus tissue removed from the body. Other schemes offer tablets at 75 cents a dozen which are claimed to reduce fat at the rate of a pound a day.

No other class of preparation exploited to humbug the people has a wider sale than these so-called fat reducers, and nearly all the preparations are absolutely worthless. Often patients seem to lose weight, but this is to be attributed to the hot baths and the diet and exercises recommended to accompany the medication.

The latest work published tends to show that the metabolism of fat people is the same as that of the lean; they use their food chemically in the same manner. Careful dieting and proper exercise are the only safe methods of weight reduction, and these must be used with extreme care especially by persons who have long carried about excess flesh. In many cases ancillary physical conditions make it unwise for fat people to try to reduce weight rapidly and as a general rule their reduction in weight should be carried out under the supervision of a competent physician who has made a special study of obesity.

By exercise of its powers over interstate and import commerce the Food and Drug Administration has removed from the market many preparations falsely labeled for cure of disease and reduction of fat. Seizures and court actions have resulted in destruction of the goods and, in some cases, fines for the manufacturers. Most manufacturers have now revised their labels to comply with the food and drug act. Some of the less scrupulous manufacturers continue to make false claims in advertisements, circular letters, pamphlets and the like, not accompanying the package, over which the administration has no legal control. For their protection the Food and Drug Administration advises purchasers to compare the printed claims on the labels of such medicines with other claims made by the manufacturers. If there is a discrepancy it is wise to depend on the label rather than on printed matter that does not accompany the package.

SELLING ENTOMOLOGY

By AUSTIN H. CLARK
U. S. NATIONAL MUSEUM

Entomology is not usually regarded in the light of a commodity subject to sale and purchase. Yet entomologists consider that their calling is of value as well as of personal interest to them, and some one else must consider it of value or they would not be able to continue their careers as entomologists.

It is my present purpose to explain just how entomology happens to be a commodity, to emphasize the necessity for securing an increased sales value, and to indicate how this desirable end may be accomplished.

Just as we can not understand the broader relationships of a tree by contemplating only its outer twigs and flowers, so also we can not understand the true position of entomology in our social scheme until we know how the seed was sown, how the little plant became rooted in our social fabric and what made it grow.

I have spoken of entomology as a tree, but it is really one of the branches of an enormous tree—the tree of science. Many times in the course of human history this tree has attained a considerable growth, has died back, then grown out again in a different direction, and again died back. It is now flourishing as never before; all its branches are healthy and luxuriant, and are constantly giving off new twigs and branches.

If the tree of science is to maintain a healthy growth its roots must reach far down into the fundamentals of human society, far enough down to receive a constant supply of nourishment from the basic sources of power in that society. So before we study the tree itself we must first examine the soil and the nutritive material afforded by it.

The fundamentals of human society are very simple. They consist of the production of foods and their distribution, coupled with the necessary defense of the individuals and social units engaged in this production and distribution. No matter how complicated a human social system may become, all lines of activity may be interpreted as functions of one or the other of these two fundamentals.

Power in any human society is ultimately based upon the ability to control, in one way or another, the production or distribution, or both, of food. Power is therefore chiefly centered in two classes in the population. The first class includes those who through the possession of wealth in one form or another are able to control far more food than they require for their own use. The second class includes those who are able to influence others in such a way as to exert a corresponding control. In any community, therefore, the real power is vested in the wealthy classes and in the politicians.

From this it naturally follows that science, as well as every other line of human activity which is not of obvious immediate concern in the raising of food, must, in order to prosper, secure the patronage of one or both these classes.

Bearing these facts in mind, let us briefly trace the history of entomology in this country. It was about the time of the Revolutionary War that insects, along with other forms of animal life, first began to attract the attention of native observers and naturalists. After the Revolution, with the progressive westward expansion of agriculture on an increasingly large scale, with the in-

tensification of agricultural operations in the Eastern states, with the cultivation of new crops, and with the appearance of new pests, native and introduced, insect depredations gradually attracted more and more attention.

As the area under cultivation became larger many agricultural journals appeared, while many journals, magazines and daily papers not primarily agricultural devoted a considerable amount of space to agriculture.

Up to the time of the Civil War by far the largest part of the published information concerning insects, especially injurious insects, was to be found in the daily, weekly and monthly papers and periodicals, especially those of the South and Middle West. As samples of journals which more or less frequently printed articles dealing with entomology I may mention the *Prairie Farmer, American Farmer, Maine Farmer, New England Farmer, Illinois Farmer, Genesee Farmer, Lancaster Farmer, Farmers' Cabinet, Southern Planter, Western Rural, Rural New Yorker, Cultivator and Country Gentleman, American Gardening, Gardeners' Monthly, Massachusetts Magazine, Iowa Homestead, De Bow's Industrial Resources,* and *Harper's Magazine.* But besides these there were many others.

Although a few were very good, most of the articles appearing in these journals were not very serious contributions to entomological literature. They were written by all sorts of people in many different walks of life; but there were at that time none who could properly be called professional entomologists.

Of the two dozen authors who up to the time of the Civil War made contributions of real worth in the field of entomology in the United States the most outstanding and conspicuous was Thaddeus William Harris, the librarian of Harvard College. Under appointment as commissioner of the state of Massachusetts he published in 1841 a treatise entitled "A Report on the Insects of Massachusetts which are Injurious to Vegetation." Subsequent editions of this report appeared in 1842, 1852 and 1862. For the preparation of this work Mr. Harris received the sum of $175, which was the first money ever paid in this country for work in entomology.

A dozen years after the publication of Mr. Harris' report—that is, in 1853—Dr. Asa Fitch was appointed official entomologist by the state of New York, the first state entomologist to be appointed, and in the same year Townend Glover, an Englishman born in Rio de Janeiro, was appointed as an "expert for collecting statistics and other information on seeds, fruits and insects" under the Bureau of Agriculture in the United States Patent Office in Washington.

Now let us look into the status of entomology as a serious study and occupation in this country in the days before the Civil War. In the time of Thaddeus William Harris—and indeed quite up to the outbreak of the war—science in general and entomology in particular was regarded as wholly unworthy of the attention of any mature person. Any one devoting his attention to science was more or less shunned; he was regarded as only one degree removed from the village imbecile—a pathetic case of arrested mental development.

Mr. Harris once wrote to his friend, Mr. Doubleday, in England congratulating him upon the fact that he was not "compelled to pursue science as it were by stealth, and to feel all the time, while so employed, that you are exposing yourself, if discovered, to the ridicule, perhaps, at least to the contempt, of those who cannot perceive in such pursuits any practical and useful results."

In England at that time science was much more highly regarded than it was in this country. Immediate practical results were not demanded there. It is

easy to say that the reason was because in England science had a social prestige which was lacking here. If the Earl of Seaforth chose to collect butterflies, or Lord Valencia saw fit to send home from distant countries pickled starfishes, humbler folk who occupied themselves more or less in the same way could not be ridiculed without showing a certain amount of disrespect for these noble lords. And in those days the lords were far too powerful to be treated with disrespect by any one but other lords.

So far as it goes this explanation is correct, but it does not go far enough. The difference in the status of science in this country and in the England of that time was simply a reflection of the difference in the allocation of power.

In England, if any one succeeded in gaining control over a very large amount of food production or distribution through the acquisition of land or any other form of wealth, he was created a peer of suitable rank, or a baronet, and according to the English system his wealth—that is his power—was passed down through succeeding generations. In the same way the successful politician who gained control over a large number of people engaged in the production or distribution of food, or the successful general who defended the food sources and markets of England against aggressive and destructive competition or who enlarged or extended them was created a peer, and if he was poor means were found of giving him wealth so that his power should be perpetuated in his family.

Thus the English system was based upon the conservation and concentration of power. Once power was accumulated it theoretically passed on unimpaired from generation to generation. Those who inherited the power were relieved of the necessity for creating power on their own account. They could, if they wished, occupy themselves wholly with unpractical affairs. This many of them naturally did, some taking up various lines of science and many others supporting science with their surplus means.

Our system was very different, especially after the Revolutionary War. Our inheritance laws were such that it was impossible to perpetuate power in successive generations indefinitely, and public sentiment was strongly opposed to all efforts toward that end.

The natural result of this was to exaggerate the importance of the personal accumulation of wealth, and hence to regard all forms of human activity in the light of their bearing on the accumulation or the display of wealth.

In both England and this country wealth and power were synonymous, as they always are everywhere. The difference between England and this country was that in England many individuals were in a position in which they were relieved of the necessity of constantly striving for power; with their inherited power, often advertised and augmented by the possession of a title which went with it, they were so secure in their position in the social system under which they lived that almost anything they might do would be considered praiseworthy. In this country, on the other hand, almost every one endowed with energy and ambition was obsessed with the desire for increasing to the maximum his personal power and prestige, and the intensity of the struggle on the part of each individual was greatly increased by the uncertainty regarding the fate of his wealth after his demise.

The natural result of the difference in the social attitude toward wealth and power in England and in this country was a corresponding difference in the type of science which found the greatest popular favor in the two countries.

English science maintained an aristocratic aloofness from the common run of human activities corresponding to the detached social status of its patrons.

The only accepted science in England was pure science, uncontaminated by any suggestion of evident economic application. To the average English scientific man the idea that his work might be of economic significance was as unwelcome as the suggestion that a lord might turn shopkeeper. The results of English research were embalmed in scholarly treatises printed in most dignified scientific journals, or in books of unassailable respectability. Naturally we had brought with us from England the same tradition, and we had already established a few excellent scientific journals, but these were all confined to the northeastern section of the country and were scarcely a factor in the growth of entomology.

Our work in entomology, largely very crude, was mainly to be found described in the pages of weekly or monthly magazines and in the daily papers, and by far the greater part of it had a direct bearing on the economic aspect. It was of no interest to any one not directly concerned with crops, and as its value in terms of dollars was not at the time evident it made no particular appeal to anybody.

While quite naturally all our scientific men of Mr. Harris' time who had been brought up more or less according to the English tradition deplored the attitude toward science in this country and envied their English colleagues, I believe it was a good thing. It put science on its mettle. Entomology especially had to fight for recognition. Recognition won by an uphill fight is always on a solid basis. And to maintain their position among recognized, accepted and respected social activities all branches of science must rest on a firm and solid basis. If science relies entirely or chiefly on the social prestige of a limited group of aristocrats it will rise or fall with those aristocrats.

In brief, up to the time of the Civil War scientific work in this country was rather sharply divided into two lines which had little in common. One line was carried on in the cloistered atmosphere and under the protection of colleges and academies where so far as possible the transplanted aristocratic English tradition was followed. The other line was a new and independent growth springing directly from the more intelligent elements in the general mass of the population. Entomology with us was chiefly of the latter type, the more philosophical phases of the study of American insects, and those aspects which required extensive reference collections and libraries being carried on almost entirely in Europe.

During the Civil War the withdrawal of the young men from civil life necessitated by the formation of armies brought about a great scarcity of labor. This had an immediate effect. Industry was hampered in all directions, which led to the rapid development of all sorts of mechanical contrivances, and the improvement of others, to enable one man to do the work of several.

In that period also the problem of food for the civil population as well as for the armies became more or less acute. This had the effect of drawing general attention to the enemies of food plants, particularly insects.

Furthermore, the social emotions resulting from the excitement of the times had the effect of breaking down to a large extent the barriers between the social classes.

So at the time of the Civil War industry combined with physics to increase its power—or rather the slowly growing rapprochement between industry and physics received an enormous impetus. The insect problem had no appeal for the industrialists, but it had an immediate appeal for another group wielding great power—the politicians in the rural districts and in the farming states.

The application of science to industry, and especially the development of

economic entomology, was very greatly aided by the social conditions of the time which tended to break down the barriers between the cloistered academic workers and the isolated and more or less untrained, though often capable and brilliant, "amateurs."

The period following the Civil War has been called a period of great intellectual awakening in this country. But people do not awaken intellectually. Through visions of financial gain or hopes of enhanced personal prestige they get their eyes opened to the advantages of adopting for practical reasons something which, in the absence of any true understanding, they had previously been apologetically calling intellectual. Reduced to its lowest terms, this simply means that knowledge which up to this time had been the exclusive intellectual property of a single class, or of a few classes, after the Civil War became of interest to, and the common property of, all classes capable of appreciating and of using it.

So what really happened after the Civil War was that industry discovered something of value in the physical sciences, while the leaders among the farmers began to find that there was something to be gained for them from an appreciative cultivation of the natural sciences. The vision of dollars looming ever more clearly in the background placed all branches of science in this country on an increasingly firm basis of social respectability.

The industries and the physical sciences are now so closely bound together that the physical, engineering and chemical departments of our universities are mainly trade schools preparing men to take their place in industrial life. By far the largest part of the research work done in physics and in chemistry to-day is carried on in the laboratories of industrial corporations or at least in close association with them.

The attainment of social respectability by science as a whole reached its culmination in the establishment by Mr. Andrew Carnegie and by Mr. John D. Rockefeller of great organizations devoted to pure science. Enormous as has been the scientific advance which has resulted from the public-spirited generosity of these gentlemen, their real contribution was that they permitted their names to be linked with pure science. In the minds of the common people, thinking in terms of purely American standards, they put the stamp of their approval, and therefore the seal of respectability, on pure science. They did just what Lord Seaforth, as viewed by English standards, had done for entomology one hundred years before.

That science is now firmly established in the appreciation of the American public was graphically illustrated by an important event that took place only a few weeks ago. At the first showing of his new picture Mr. Charles Chaplin had with him as his guests of honor Professor Albert Einstein and Professor Robert A. Millikan. What does this mean? Fundamentally, of course, it means that Mr. Chaplin saw in Professors Einstein and Millikan possibilities for more free newspaper space devoted to his new picture than could be secured by the presence of any other guests. Conversely, it means that science, as represented by relativity and cosmic rays, holds the public interest at least to the same extent as a new picture by Charles Chaplin. In the light of the differences between our social system and that of England this event was, so far as the recognition of science is concerned, quite the equivalent of the bestowal of a peerage on Sir William Thomson (Lord Kelvin) in 1892 and on Sir John Lubbock (Lord Avebury) in 1900 by Queen Victoria.

Now let us return to entomology. During the Civil War C. V. Riley, a young Englishman, published some

articles on economic entomology in the *Prairie Farmer*, with which he later became connected as reporter, artist and editor of the entomological department, this work being interrupted by a short period of service in the 134th Illinois Volunteer Regiment. In 1868 he was appointed state entomologist of Missouri, and while in this position published a series of nine annual reports which may justly be called the American classics in economic entomology.

At the close of the Civil War flights of that destructive grasshopper known as the Rocky Mountain locust had caused considerable damage, and in 1874–76 this insect became a really serious menace to agriculture in the regions west of the Mississippi. The very extensive depredations of the locusts received more or less notice in all the papers in the country.

As a result of Mr. Riley's efforts, Congress on March 3, 1876, established a commission, under the direction of the United States Geological Survey, to investigate the Rocky Mountain locust. The commission was composed of Mr. Riley as chairman, Dr. A. S. Packard, Jr., secretary, and Dr. Cyrus Thomas, treasurer. The establishment of this commission was an important event in being the first real recognition of the desirability of supporting organized scientific work in economic entomology under Federal auspices.

Having now become a well-known national figure, Mr. Riley was appointed entomologist in the Department of Agriculture in June, 1878. In this position he served continuously until June, 1894, except for a period of two years when he was replaced by Professor John H. Comstock.

From the time of the Civil War the study of entomology has rapidly advanced. The number of entomological organizations and of entomologists has steadily increased, and various entomological journals have been founded. It is not too much to say that this advance in entomology has been mainly the result of Mr. Riley's work.

I have traced Mr. Riley's career at some length in order to emphasize the very important fact that his success rested on the appreciative regard for him on the part of the plain people. Through the popular contacts made while he was on the staff of the *Prairie Farmer* and his understanding of the average man, he was able to develop to the maximum the position of state entomologist of Missouri. With the development of numerous additional contacts made while holding this position he was able to bring about the establishment of the Rocky Mountain locust commission, and his work as chairman of that commission made him the logical choice for entomologist in the Federal service at Washington. Of course, had it not been for his extraordinary natural ability he could not have succeeded as he did. At the same time had he not had the opportunity for making broad popular contacts, and the capacity for developing those contacts, his natural ability would have availed him little.

At the present time entomology is in danger of losing those intimate popular contacts which were so firmly established by Mr. Riley and greatly broadened and extended by his successor, Dr. L. O. Howard. Entomological, like academic, salaries are largely fixed, continuing unchanged, or at least undiminished, from year to year. This in itself gives rise to a feeling of security and a sense of detachment from the world at large which tends to obscure a true appreciation of social responsibility.

But we must always remember that in entomology, especially in economic entomology, the power which serves to support and to further research work is lodged in the hands of the representatives of the people. For insects are more of a menace to those directly con-

cerned with the growing of farm products than they are to any one else. So we find that by far the greater part of entomological work to-day is being carried on by means of money raised by general taxation, federal or state, and is more or less immediately under the control of politicians who derive their support more or less directly from the population of farming areas.

Now politics is the science of the possible as applied to human affairs. The average politician must act strictly in terms of the wishes of his constituents. If you wish to do business with him you must talk the language of his constituents, for that is the only language he understands. You must always remember that he will pay more attention to a laborer in his district than he will to you, because that laborer with his vote may affect his future career. Naturally it wounds our pride to have this brought home to us, yet no politician would be worthy of the trust imposed in him if he did not think more of his constituents than he does of us.

As a professor of the great science of the possible the average politician can only afford to see what is more or less clearly visible to his constituents. Therefore the more enlightened his constituents are on any subject, entomology included, the more enlightened he will be.

Most people depend for their knowledge of things in general, and of what is going on in the world about them, on the daily press. This may be supplemented by various magazines and books, but broadly speaking the daily press is by far the most potent factor in general education. Some newspaper or other is read by, or to, every constituent of every politician. You will find that for the most part the average man's idea of entomology is a composite of the ideas conveyed to him through his favorite newspapers and magazines.

Since the support of entomology in this country is vested chiefly in the hands of politicians, big and little; since in the nature of things politicians are primarily spokesmen for their constituents; and since these constituents are educated entomologically, as in other ways, chiefly by the daily press, it naturally follows that the status of entomology as a science with us will be dependent upon its exposition and interpretation in the daily press.

From what has been said it is evident that the study of entomology first began to attract the serious attention and support of the American people when it was presented to them by Mr. Riley and others in the light of something of real and tangible value—that is, in the light of a commodity worth buying. It is further obvious that further expansion of entomological work is dependent upon the hope and expectation of increased benefits to be gained—that is, upon an increased sales value.

It remains to be shown how the public appreciation of the facts of entomology, and of the benefits resulting from the study of insects, may be increased.

The responsibility for this rests directly upon the shoulders of the entomologists themselves. It is their duty to see that the readers of the public press, who provide the support for the greater part of the work now being carried on in entomology, are themselves provided with abundant and accurate information on the subject.

Entomology has now become so very technical, and entomological work is so time-consuming and exacting, that it is no longer possible for working entomologists to supply the press directly with the required information. Yet at the present time the press desires and can use far more information than can be supplied. Perhaps the greatest stumbling block in the way of supplying the press with the desired material is that the language of the press and the language of entomology are very

widely different. Yet it is the plain language of the press that must be used in reaching ordinary people. To the average reader larva means molten rock, nymph means a kind of outdoor chorus girl, and pupa means nothing. Can we overcome this difficulty?

This difficulty was foreseen and has been overcome by the press itself, on its own initiative. Entomologists have at their service a corps of able interpreters writing the language of the press but with a thorough appreciation of, and respect for, science.

In 1921 Mr. E. W. Scripps established an organization known as Science Service, the function of which is to provide the press with news or information on scientific subjects accurately written in popular language. Science Service is at present under the direction of Dr. Vernon Kellogg, well known as one of our most eminent entomologists.

Since that time science has rapidly gained in popular favor, and one by one the great press services, groups of papers and large independent dailies have designated special men of proved ability as "science editors," whose business it is to see that scientific news and information is properly presented in the papers under their control.

There are now about fifteen of these science editors, all but two of whom are college men. They come from Harvard, Amherst, Cambridge (England), Western Reserve, Columbia, Cornell, George Washington, New York University, the University of Illinois, the University of Michigan, the University of Chicago. the University of London, and some other universities. Two at least are doctors of philosophy, and two themselves give courses in universities. Of the two who are not college men, one received the Pulitzer prize for his accurate and brilliant work in reporting the Boston meeting of the American Association for the Advancement of Science in 1922.

These men are among the outstanding writers of the country. They write in the language of the press, yet at the same time appreciate and are able to understand the language of science. They are the interpreters of science, and at the same time its salesmen. Between them they provide most of the scientific items that appear in more than three thousand papers. The output of one of them alone goes to nearly thirteen hundred papers. The press is doing everything it can to present science to the people in the proper light.

There is another difficulty. What sort of science do the people want? As I said before, ours is a business country. We take the business attitude toward everything. With us science is a business, or perhaps more truly a department of a larger business. In order to prosper it must be advertised and sold, just like any other business, and in much the same way as any other business.

Each country has its own peculiar attitude toward science. I may illustrate this by a little story. One evening a number of friends were gathered together—an Englishman, a Frenchman, a German, a Pole, a Russian and an American. After a long and perhaps too convivial discussion they agreed that each should prepare a treatise on the elephant. The Englishman spent a year in Africa and after his return produced an entertaining little volume entitled "Elephant Hunting in East Africa." The Frenchman spent six months in Africa and six months in India and published a little book called "The Elephant and his Love Affairs." The German spent five years in the field, visiting all the regions wherein elephants are to be found, and then five years working in the libraries of Berlin, after which he produced a huge two-volume quarto entitled "An Introduction to the Definition of an Elephant."

The Pole thought it unnecessary to leave Warsaw. After a year or so he produced his book, which was called "The Elephant and Its Bearing on the Polish Question." The Russian also found it unnecessary to leave home. After due deliberation he produced a delightful iconoclastic book entitled "The Elephant—does it Exist?" The American joined a Cook's tour around Africa and India and on his return wrote an inspired treatise called "Bigger and Better Elephants."

Now there is no denying the fact that the American people like to read about bigger and better science. The calm cold expositions of scientific fact one reads in the English and in the German press could never be printed here. Popular presentation must be to a certain extent along bigger and better lines. Yet even in this respect a compromise can easily be reached which will not be too distasteful to the most solemn of scientific men. Some years ago physics and chemistry overcame all squeamishness in this matter, and entomology can do the same. Is calling *Melanolestes* a "kissing-bug" any less dignified or detrimental than referring to cosmic waves as a "humpty-dumpty phenomenon"?

Any form of human activity is appreciated in proportion to the amount of space devoted to it in the newspapers, just as the importance of any firm or corporation is judged by the relative size of its advertisements. Thus in this country murder is regarded as one of the most interesting and entertaining of human occupations. So for newspaper space science must compete with murders—bigger and better murders.

You may not realize it, but newspapers do not like to put emphasis on murders. Even the most sensational among them prefer to print other kinds of news. But in order to live papers must print what the people wish to read. In order to replace murders the papers must have something to print which is equally entertaining, or can be made equally entertaining, for the average person. As there is a fixed amount of space available in a newspaper, any increase in the amount of scientific news and information published is at the expense of other types of more or less similar material. The interest of the scientific information therefore must be equal to that of the material replaced.

Now writing for popular consumption is a specialty which has as a prerequisite natural aptitude based on exceptional mental equipment. This natural aptitude must be developed by a long process of intensive training under conditions involving constant and most bitter competition. A successful writer is in capacity and in training quite the equal of the successful delineator of the embryology, life history or ecology of an insect. While he may be stricken completely dumb by the description of a new species of chalcid fly, he can describe protons, electrons, the red shift, etc., in such a way as to flatter you into thinking you know what he is talking about. And after a short interview you will find that he can describe a chalcid in such a way as to make a physicist believe he understands the creature, and furthermore wish to know more about it.

It is chiefly because of the extraordinary ability of these writers on science that the relative amount of science printed in the papers is rapidly increasing at the expense of other types of material, and correlatively that public appreciation of science is rapidly increasing.

Now in this increase in the amount of science appearing in the public press entomology has not participated to anything like the extent that was to have been anticipated in view of the fact that of all branches of science in this country the study of insects is perhaps most

closely dependent on the good-will and support of the people; that entomology in America may almost be said to have arisen from the people, as evidenced by the great amount of material which in the early days was published in popular journals; and that the greatest figure in American entomology laid the foundation for his work by writing for a popular journal. It is high time that entomologists took steps to correct this situation.

I shall close with a word of warning. As things stand at present we are facing a distinct and growing menace. We are developing a mechanistic and dehumanized culture which is rapidly becoming unintelligible and therefore irksome to the great bulk of our population. Signs of a reaction are already at hand. We are beginning to show symptoms of philosophical indigestion. Mechanization is proceeding faster than the development of our ability to incorporate it into our ideas of things as they ought to be. Materialistic as we are, we are outrunning our philosophy. As an illustration, biographies lately have become extremely popular. We do not care whose biography we read, but we like to be taken back to the days in which the subject lived. Life as it was in those days appeals to us. Conversely, dehumanized dial telephones do not, in spite of their superior efficiency.

The chief requisite of science as it is portrayed to-day in the daily press is a return to fundamentals—more extended notices of these lines of science which after all come closest to us. We must have more information on living things, and especially on those living things that immediately affect our welfare. Chief among these are the insects.

SCIENCE SERVICE RADIO TALKS

PRESENTED OVER THE COLUMBIA BROADCASTING SYSTEM

THE INDIANS OF THE DISTRICT OF COLUMBIA

By Dr. WALTER HOUGH

HEAD CURATOR, DEPARTMENT OF ANTHROPOLOGY, U. S. NATIONAL MUSEUM

THERE are many evidences that before the coming of the white man Indians had their villages in what is now the District of Columbia. These Indians spoke the language of the great Algonquian family which covered the east coast, and for this reason the Algonquians were met by John Smith at Jamestown and by the Pilgrims at Plymouth. Much more is known about the Virginia Indians than of the northeastern tribes seen by Winthrop, because Sir Walter Raleigh sent along with John Smith a competent artist who drew pictures of the natives, their houses, dances, occupations, and of animals of the sea and land. Accustomed as we are to the buckskin of the western Indians, we will be surprised to know that Powhatan's braves had nary a shirt to their backs, robes taking their place. The women wore short skirts and the children dispensed with clothes. Of course, in the cold months of winter the Indians withdrew into their houses and enjoyed the stores of corn, smoked fish, hickory nuts and such things as they had laid up. The houses were of bent poles covered with mats and were in shape like a hayrick seen on farms.

Such houses were spaced with some regularity into villages, surrounded by cornfields, and having a dance plaza smoothed by the bare feet of the celebrants around the central fire. Secotan was a scattered village among the trees, while Pomeioc was massed in a circular palisade of sharpened stakes. John White made pictures of these towns and they may be regarded as typical Algonquian architecture and village planning. We may thus restore to the mind's eye a great village on the Eastern Branch and call it the ancient capital of this region.

It may seem unfortunate that the District of Columbia Indians left so few traces of their life here. Archeologists trained to the work are able to see much in small things and to tell the story without straining the imagination. One picks up an arrowhead, say, at Anacostia. It is of a certain stone and worked from a boulder most likely at the Piney Branch quarry. He knows that the arrow was fixed with sinew at the end of a wooden shaft, straight and smooth, which was notched at the end to receive the string; also that it was feathered to guide its flight.

He knows further that there was a bow to project the arrow and that it had a sinew or Indian hemp cord. Then it is evident that there was a man in charge of the bow, arrow, quiver, and so forth. The arrowhead was found at Anacostia, inhabited by the Nacotchtank Indians, and we have got our man, equipped for the hunt or battle. The arrowhead was found at Anacostia and belonged there because it is the right kind of stone. Another variety of stone would indicate that it was a point made by the hostile Indians living on the Susquehanna or where the certain stone was found. Perhaps the archeologist picked up a fragment of pottery and derived a most interesting story from it. Especially it would tell him that the Indians lived in a village of houses because fragile pottery can not stand rough Indian transportation, and was therefore made on the spot from native clay.

So the story widens with the bits of

the old times picked up, everything having an Indian man or woman once living and breathing at the other end. The hunt for the Indians is not made with a spade and the fingers, but with the informed mind. The District of Columbia Indians were in the stone age, and imperishable stone tools left in the soil are silent though eloquent of the old times. So many of the implements are of a stone called quartzite that archeologists earnestly desired to know what was the source. Dr. W. H. Holmes and De Lancey Gill, archeologically sleuthing here and there over the District, found quartzite boulder beds in the once beautiful valley of Piney Branch and saw chips and partially worked cobble stones lying about. Here, said Dr. Holmes, appears to be the quarry. Subsequent ditching revealed that here was one of the greatest Indian quarries discovered in the United States.

Thousands of tons of chips and other quarry refuse lay under the tree-covered gentle slopes of Piney. Dr. Holmes' trenches showed that the boulder bed had been worked in places to the depth of 28 feet. An incredible amount of labor had been expended here to fashion by blows of stone upon stone leaf-shaped blades, the blanks from which arrowheads and knives were made in far-off camps. In the old days of the District of Columbia a temporary camp of mat houses would be seen on the level tract of Blagden's, above the quarry. This village site was discovered by the speaker when the war garden bared the soil undisturbed by the plow for more than a century.

The river life of the Potomac in 1608 must have been very interesting. John Smith tells of divers savages in canoes, well laden with the flesh of bears, deer and other beasts. Some of these dug-out canoes are in the Potomac mud no doubt now. There were many places to paddle not open to-day. Boats could move about freely where the new government buildings are going up, and the Eastern Branch was a great river 300 years ago. At night, reflected in the undulating Potomac, were the lights of the torches of fishermen, and over the smouldering fires of the primitive gridirons the catch was smoked for the winter. Down the river and around the coast went canoes filled with furs, meat and corn for aboriginal trade.

Land trails also centered in the District, leading to the Susquehanna and on to the West. Braddock used an old trail to Cumberland worn deeply in old times by Indians in moccasins. Railroads must follow these old trails in another day, giving little thanks to the native road builders. Sometimes among the débris of lost villages one comes upon a bit of fashioned soapstone, a shard of an ancient vessel. Thin, smooth and well formed, this bit shows the skill of the Indians of the District of Columbia. Not satisfied with determining the size and shape of a soapstone pot from a fragment, Dr. Holmes sought out the places where the Indians quarried soapstone, finding several small quarries in the District where they had worked. The story could not be completed here, but in a quarry in the old District towards Alexandria he found bosses of soapstone worked out on the face of a deposit. The bosses were the round bottoms of future soapstone pots, the next step being to knock these bosses off and excavate them with the rude pick chisels of stone left about by the workers. Thus lightened, the unfinished pots were carried to the camps and finished to the taste of the cooks who had use for them.

In its natural conditions or only slightly aware of the presence of man, the District must have been an ideal place for savage life. Every family could have a deer a day and not decrease the herd; a bear once in a while, wild turkey, water birds, fish, roasting ears and ripe corn would vary the fare. Not too thickly planted by nature for the

Indian, also, but a dare to the early American with his steel axe. Its massive trees were his harvest.

The coming of the white man to Jamestown in 1607 was a small entering wedge into a vast territory, and perhaps we would think it of little effect on the District. On the contrary, in 75 years there was not an Indian left in the valley of the Potomac, the same story that became old as the white man pushed the remainders west. The District was settled by hardy pioneers and a new line of history began.

TELLING THE NATION'S TIME

By Captain FREDERICK HELLWEG

DIRECTOR U. S. NAVAL OBSERVATORY

I WONDER how many of you have ever given any thought to the question of how the nation's time is obtained, how it is kept, how it is transmitted to the millions of people, and how important a part accurate time plays in the life of every one.

How many times a day do you suppose the question is asked by some one: "What time is it?" Ask the Western Union Telegraph Company why they had to stop telling people the time. Thousands and thousands of telephone calls all over the country were pouring in on the telegraph company's offices: "Will you please give me the correct time?" until the interference with their business was so serious that they reluctantly had to refuse to answer the question. The U. S. Naval Observatory had to stop answering the question for the same reason. Our telephone lines were being choked by requests for time so that our legitimate business was interfered with. I have told you this to show you how many times a day some one wants to know the time.

The duty of keeping the nation's time is a very important and a very technical one. Every nation in the world maintains a costly time service, for you know the determination of the time is expensive. Instruments for observing the stars, chronographs for recording the exact instant when the celestial bodies cross the meridian, precision clocks for maintaining the time accurately—all these are very expensive. Then add to this the cost of the labor, including astronomers who observe nightly the stars as they cross the meridian of the observatory, the highly technical computers who calculate the time based on the observations, the electricians who handle the many electrical details of keeping the time, the radio experts who broadcast daily the exact time to the hundredth of a second, the telegraph personnel who signal the time to all parts of the continental limits of our country, all these make the sum for keeping the nation's time mount very rapidly. And yet, it is well worth it. Without accurate time many things could not be developed.

Do you know that mineralogists and geologists depend on the Naval Observatory's exact time to assist them in hunting for the vast oil deposits hidden away in the bowels of the earth? Would you be surprised if I told you that scientists depend on the observatory's time signals in their investigations of gravity? Of course you all know that the navigators on ships at sea listen daily for our time signals in order to navigate their ships safely across the seven seas.

How many of you know that all the important boundary commissions which determine the boundary lines between nations, between states, and between communities are dependent for the es-

tablishment of their lines accurately upon the time signals broadcast from the observatory? To show you how extensive is the use of our time signal, in 1921 the Naval Observatory broadcasted a special time signal upon the request of the Australian Boundary Commission, which was establishing the boundaries between the provinces in Australia. This last summer we were requested, and later thanked, by the director of the Canadian Geodetic Survey, for our assistance in their boundary work between the provinces of Ontario and Manitoba, and also for our assistance in their work in Saskatchewan. Without exact time, the wonderful train service that spreads throughout our land would be a hopeless mess and the loss of life would be very great. There is hardly any activity in our entire country that is not directly affected by the question of time.

Before telling you how we keep the time, it may be of interest to you to know that the initial effort in the United States was made by an amateur astronomer, William Lambert, who presented a memorial to Congress in 1809, recommending the establishment of a first meridian in the United States at Washington. Lambert had determined the longitude of Washington and submitted his calculations with his memorial to Congress.

In 1845 observations of the sun, moon, planets and brighter stars were inaugurated at the observatory and have been continued ever since. In 1849 the first practical chronograph, called a magnetic clock, was built. That was the first time that electricity had been employed in the recording of observations at the observatory. This old clock is now in the museum at the Naval Observatory. Between 1854 and 1860, three minor planets were discovered by the Naval Observatory astronomers, but it was not until 1873 that the observatory was equipped with a large refracting telescope. At that time it was the largest one in this country.

Having given you this brief history of the U. S. Naval Observatory, the place where the time is kept, and the place which tells the time to the nation, I will now briefly describe how we calculate the time and broadcast it to the world.

As the earth rotates, the stars in the heavens appear in the east and after swinging across the heavens set in the west, just as the sun appears to do. The only difference between the sun and the stars is that the stars appear to make the round-trip in almost the true period of the earth's rotation, while in the case of the sun a little more than a revolution is necessary to bring the sun back again to the meridian. I will not explain the reasons for this as any one can obtain them from any book on astronomy in any of the public libraries. As the stars are not within the earth's orbit (in fact they are so far distant that their apparent positions are only very slightly affected by the earth's motion), the period of the earth's rotation, measured in reference to a point in the sky called the vernal equinox, is one sidereal day. This period is the most accurate standard of time measured. The earth's rate of rotation is constant and the stars move very slowly with reference to the vernal equinox, so that they are very reliable as reference points to measure the time of the earth's rotation.

Here at the observatory we use small telescopes, known as transit instruments, for observing the stars. These instruments, as their name indicates, are used to mark the exact instant the star passes across the celestial meridian. The celestial meridian is a line in the heavens which passes through the north and the south points and also through the zenith of the place where you are situated. The sidereal time at which each star will cross the meridian is calculated. For greater accuracy we select the stars

which cross the meridian near the zenith of Washington, and also the stars whose exact positions are most closely known.

The exact time, according to the clock, that the stars cross the meridian is very closely determined, and the difference between the time that the stars should cross the meridian and the times they are found to cross the meridian according to our clock, is the error of the clock. These errors are very accurately determined.

Down in a vault, specially made, and maintained summer and winter at a uniform temperature and at a constant air pressure, are three standard sidereal clocks which keep the most accurate star time possible. These clocks are never reset or interfered with in any way except in the case of necessity for repairs. The actual rate of each clock is determined by checking with the actual time the stars cross the meridian, and then by applying these corrections to the face time of the sidereal clock, we know the exact sidereal time.

The standard time of the United States is called "standard mean solar time." Owing to the irregularity of the earth's motion in its orbit and to the inclination of the earth's axis, apparent solar days vary in length during the year. For obvious reasons it is necessary that all days and all hours be of the same length, therefore a mean solar time has been established and this is sometimes ahead of and sometimes behind the apparent solar time, but on the average it is the same.

In order to reduce confusion, standard time zones have been created. All the points in each zone use one uniform time. These zones are on even hours and are measured from Greenwich which is considered the zero meridian. For instance, in continental United States there are four time zones—the Eastern standard time is the local time of the 75th meridian and this is exactly five hours behind the Greenwich standard time; Central standard time is the local time of the 90th meridian which is six hours behind Greenwich time; Mountain standard time is the local time for the 105th meridian which is seven hours behind the Greenwich time; and, the Pacific standard time is the local time of the 120th meridian which is eight hours behind the Greenwich time; and the servatory is thus able to furnish one time signal which will provide time for all the zones. Our time signals are sent out at noon, at 10 o'clock in the evening and at 3 o'clock in the morning.

The time signals are broadcast automatically by means of special transmitting clocks. These clocks contain electrical mechanism by which they may be set within one hundredth of a second. They also have an electrical break circuit apparatus for emitting the signals. Before each signal these transmitting clocks are compared with the standard sidereal clocks in the vault by means of a chronograph, and are then set electrically within a hundredth of a second of the correct mean solar time. From 2:55 A. M. to 3:00 A. M., from 11:55 A. M. to noon, and from 9:55 P. M. to 10:00 P. M., Eastern standard time, dashes are broadcast, beginning on each second except that there is no dash transmitted on the 29th second of each minute, nor on the identification seconds at the end of the minutes. This is done so that any one listening will know that if one beat is missed the next beat will be the 30th second of a minute. From the 55th minute up to and including the 58th minute there are no ticks for the 56th, 57th, 58th and 59th seconds. This lets you know that the next tick, after omitting four beats, represents the beginning of the minute. On the 59th minute there are no beats sent from the 50th second until the 60th second. This allows any one who is listening for the tick to realize that after the silence of nine seconds, when the next tick is

sounded it is the zero hour—either 3:00 A. M., noon, or 10:00 P. M. The telegraph companies transmit only the noon signal, and in transmitting the noon signal they only transmit the last three minutes. They used to transmit the whole five minutes but for economy's sake they shortened the time to three minutes.

Our time signals have been broadcast by Arlington on high power since December, 1912. Our time service goes much farther back than that, as the first time signal was broadcast by the Navy in the spring of 1904. But it was not until 1912 when the big Arlington station was completed that it was possible to broadcast our time signals with sufficient power to reach around the world. As you all know, radio signals are much better received at night than during the daytime. We therefore inaugurated the 3:00 A. M. time signal for the convenience of observers away out in the Pacific.

The Naval Observatory is a national institution and many visitors to Washington avail themselves of the opportunity to visit it, and view the many very interesting things here. As the observatory is our national observatory, your observatory and mine, it is believed that every visitor to Washington should make it a point before leaving town to spend a few hours very profitably going through this very wonderful institution.

HOW UNITED STATES PAPER MONEY IS MADE

By A. W. HALL

DIRECTOR, BUREAU OF ENGRAVING AND PRINTING

As your announcer has just stated, I am talking to you from a press room in the Bureau of Engraving and Printing, at Washington, D. C. The humming sound you hear in the background is that of machinery producing paper money. Every five seconds one printing press turns out twelve notes. There are 240 presses in daily operation. When these presses are engaged upon the printing of one-dollar bills the output averages $28,000 a day for each press, and when printing twenty-dollar bills the output averages $560,000 a day for each press.

I shall attempt to describe, in non-technical terms, the various operations employed in the production of paper money. Before going into details I want to give you briefly some general information regarding the Bureau of Engraving and Printing. It was not until July 11, 1862, that the United States government undertook to engrave and print its own securities. In keeping step with the ever-increasing demands made upon it, the bureau has gradually grown until to-day it employs 4,500 persons to whom $10,000,000 are paid yearly in salaries and wages. The building which the bureau occupies is located on the bank of the Potomac River about one mile south of the White House. The main building, which is of Roman Doric architecture and of limestone and modern construction, is 555 feet long, 296 feet deep, and 105 feet high. The main building provides ten acres of floor space, while the auxiliary buildings provide about four acres. In addition to the production of paper money, this bureau prints all the postage stamps, revenue stamps, bonds, certificates of indebtedness, disbursing officers' checks, liquor prescriptions, transportation requests, commissions, warrants, and numerous other classes of engraved and lithograph work for the United States government and its insular possessions. Of the total person-

nel, 55 per cent. are women. During the last fiscal year the face value of securities printed and delivered by the bureau amounted to fifteen billion dollars. In addition to this 12,500,000 sheets of checks, drafts, commissions, certificates, etc., were also printed.

Last week the Honorable Walter Ewing Hope, assistant secretary of the treasury, described the various kinds of paper money in circulation. This afternoon I shall endeavor to describe the many processes employed in preparing these various kinds for circulation. Except for the final operation on national bank currency, the processes employed in producing paper money are identical for all kinds. You will notice that the national bank currency bears the name of the bank of issue, the charter number and the signature of the bank officers, which are not required on United States and Federal Reserve currency.

The first step in arranging for the production of paper money is that of preparing the designs. When a new issue, or a new note, is to be placed into circulation this bureau consults with the officials of the various offices involved, and the conclusions reached as to the character of the design are embodied in a model. After this model receives the approval of the Secretary of the Treasury, the design is reproduced in soft steel by several expert engravers, each one engraving his allotted portion. Since each engraver specializes in different lines of engraving, such as portrait, vignette, ornamental, lettering, etc., the entire design of any one note does not represent the work of any one engraver. Sometimes as high as six different specialists in engraving are employed in the engraving of the completed note.

The work of the various engravers who contributed to the design on the note is then brought together on one piece of soft steel, which, after having all imperfections removed, is hardened. The hardening of this steel is accomplished by heating it in cyanide of potassium and quickly dipping it in cold oil or brine. This piece of steel is known as the die and it is never used for printing, for the reason that the large number of impressions required to be printed would soon wear it out. The hardened die is placed on a transfer press and a soft steel roll is rolled over it under tremendous pressure until the soft steel of the roll is forced into the lines of the engraving of the die, reproducing the design in relief on the circumference of the roll. The roll is then hardened and rolled over a soft steel plate, thereby reproducing an intaglio, or cut-in, impression on the plate. The engraved plate, when hardened by the same process as employed in hardening the die, which is done to increase its durability, is cleaned and made ready for the printer. By repeating these transfer operations an unlimited number of steel printing plates of perfect duplicate engravings can be made from one original engraved die.

Within recent years a new process of plate making was developed in this bureau. This new process is accomplished by electro-deposition, and plates made by this process are called electrolytic plates. Some idea of the principle of the electro-deposition may be gained from the nickel-plating equipment of your local jeweler. First a steel plate is placed in a chemical bath and a layer of copper deposited upon it. When the copper is separated from the steel plate we have what is called an alto plate, bearing the design in relief. This alto is placed in a bath, upon which are built alternate layers of nickel and copper, and which when separated from the copper plate has the design in intaglio or cut-in form. The face of this plate is hardened by the application of two ten-thousandths of an inch of chromium, a metal next to the diamond in hardness. Both steel and

electrolytic plates are used in this bureau for the printing of paper money.

Only the highest grade paper is used for printing paper money. It is manufactured by private contractors under government specifications and supervision. Red and blue silk fibers are distributed throughout the sheets, so as to make this paper distinctive. It is a violation of the statutes for any unauthorized person to possess any of this distinctive paper, except in the form of lawfully issued currency or securities.

All the ink used in printing paper money is manufactured by this bureau through mixing dry colors, bases, oils, etc., in large kneading mixers, which resemble those seen in large bakeries for mixing dough. Barytes is the base for most plate inks. The dry colors are made from coal-tar dyes, ground minerals and chemical precipitations, more of the latter two being used on account of their resistance to light and atmospheric influence.

The blank sheets of distinctive currency paper are received in lots of one thousand sheets, and every blank sheet brought into this bureau is charged against the bureau on the books of account maintained by another office of the Treasury Department. Each sheet passes through a specially designed device called a wetting machine. In this machine the sheets pass under a spray of water which makes them soft and pliable and receptive to the ink. Four days after the sheets pass through the wetting they are ready for the first printing operation. The back of the note is printed first. Each printer operating a press calls for the number of sheets he can print in one day. He obtains this paper from the division in which the paper is prepared for printing. The printer is charged with these sheets. The press upon which the printing is done is called a four-plate power press. The printing plates are strapped to attachments called planks and the four planks each carry a plate which travels in circular fashion. At one point the entire face of the plate is covered with ink, at the next point the surplusage of ink is wiped off by a mechanical oscillating wiper. Then the printer polishes the plate with his bare hands, taking care to leave the cut-in lines of the plate filled with ink. A blank sheet of the moistened paper is laid on the plate, and immediately following this the plate with the paper on it passes under a pressure roller. The pressure exerted by this roller forces the paper into the lines of the plate and the paper takes up the ink. The sheet is then picked off the plate. The four plates continue in this fashion without interruption during the time the press is in operation. As each impression is made a mechanical counting device registers it. Every two hundred printed sheets are removed from the press and hand counted. At the close of the day the requisition signed by the printer for the number of sheets withdrawn for printing is checked against the amount reflected on the mechanical counting register and the number of sheets counted by the representatives who remove them from the press. A reconciliation of these three amounts must be accomplished before the printer or his assistants are permitted to leave the building.

All sheets printed during the day are sent to a large room, which is heated by steam, where they remain overnight. During the night the moisture is driven out of the sheets and the surface of the ink dried sufficiently to permit handling. The slip sheets inserted at the time the currency was printed are then removed and each sheet given a careful examination by experts. Sheets bearing the slightest defect are rejected. The perfect sheets are returned to a vault where they are permitted to dry out for a period of three or four weeks before starting through the next print-

ing operation. The second printing operation, or that of printing the faces, is likewise preceded by wetting. The operation of printing the faces is identical with that of printing the backs. The perfect sheets continue through subsequent operations. The imperfect are delivered to another agency of the department, which certifies to their destruction, giving this bureau credit on the books of account for the amounts so destroyed.

Next the sheets are resized. In this process the sheets pass through a solution of glue, the thin coating of which makes the paper more durable. The sheets are then pressed by a process known as calendering. In this process the sheets of currency are interleaved with a heavy cardboard, and packs of sheets arranged in this manner are sent through a set of large rollers. These rollers exert tremendous pressure, which irons out all the wrinkles and restores the gloss. Next the sheets are trimmed to the required size by a machine which takes the margin off the four sides at one time. The serial numbers and United States seal are next printed on the face of each note. In this operation the sheets are automatically fed into a very unique machine which not only prints the numbers and seals on each note, but simultaneously slits the sheets in half. Each half is delivered to another section of the machine and drawn through a set of slitting knives which reduces each half to six separate notes. The notes are dropped into a collator, which mechanically gathers them up in numerical sequence and delivers them to an examiner in packages of one hundred. After careful examination the notes are banded in lots of one hundred each. Forty of these packages of one hundred notes are strapped together by steel bands, which are electrically welded. An outer covering of brown paper bearing the label showing the contents completes the package for shipment to the various issuing agencies.

The annual output is approximately one billion notes, the production of which consumes 1,125 tons of paper and 1,100 tons of ink. In passing through the many operations a sheet of currency is hand counted fifteen times and mechanically counted three times.

Within recent years the public has become so much interested in the work of the bureau that it has been found advisable to publish a pamphlet explaining the various processes and operations employed in printing not only currency but the many other classes of work produced by this bureau. This pamphlet is on sale at the office of the Superintendent of Public Documents, Washington, D. C., at 10c a copy. When you visit Washington you should make it a point to see the bureau in operation. It is open to visitors during certain hours of the day.

PHILOSOPHICAL IMPLICATIONS OF MODERN PHYSICAL SCIENCE

By Professor J. RUD NIELSEN
DEPARTMENT OF PHYSICS, UNIVERSITY OF OKLAHOMA

THE influence of science upon modern life is largely indirect, taking place by way of technology. Through the ever-multiplying horde of machines profound changes are being wrought in the environment of human beings, and men are given a greater and greater potential control over their own destinies. What use will they make of these newly acquired powers? What revision of human ideals and social instrumentalities is demanded by the new situation? These are very pertinent questions which form perhaps the most important challenge to philosophy at the present time.

In addition to this indirect influence upon philosophy, especially upon the theories of human values, science has a direct bearing upon the general theory of knowledge. After all, any theory of knowledge worthy of attention must be derived from a study of the procedure by which knowledge is actually obtained, *i.e.*, from an examination of scientific method. It is natural, therefore, that the enormous extensions of our knowledge of the physical world in the last generation, which have necessitated the first really deep-going revision of the fundamental physical concepts and axioms since the days of Newton, should present important problems and correctives to epistemology. To point out some of these is the purpose of this article.

Before starting, let us settle a question which may have entered the minds of some of my readers. With what right does a physicist undertake to discuss philosophical problems? Ought he not to confine himself to physics and leave philosophical questions to the philosophers? Well, that is what physicists have generally done. But frankly, I consider it well within the right of a scientist to discuss any problem which has grown out of his science, even if the problem is of a very fundamental and general nature. And such problems are forced upon physicists, for, as Helmholtz once said, no matter what physical problem one starts with, if one pursues it far enough it will become a philosophical problem.

Moreover, in attacking a philosophical problem the physicist does not necessarily step outside the boundaries of his science. His problem does not cease to be a physical problem when it has become so general that it is properly termed philosophical. There is no sharp dividing line between physics and philosophy. As the Austrian epistemologist Schlick says, "Philosophy is not an independent science—rather is it hidden in every science as the true soul of science." The greatest among scientists have been inspired by motives which may rightly be called philosophical. As W. F. G. Swann writes in a recent issue of *Science*, in commenting upon Einstein's publications, "It has been our philosophic desire rather than the needs of experiment which has driven us to hope for a correlation of gravitation and electromagnetism in one general scheme." The work of Bohr on atomic structure has been inspired by the dream of being able to derive all properties of a chemical element from a pure number, the number giving the place of the element in the periodic system of Mendeleeff.

Mechanics is the oldest physical science. In fact, by the end of the eighteenth century it was developed by

Newton and his followers to nearly the degree of perfection that it possesses to-day. In the nineteenth century the importance of mechanics was immensely enhanced when it was found that many phenomena which do not offhand appear as belonging to mechanics could nevertheless be described quite adequately in mechanical terms. Thus we got a mechanical theory of heat, and the phenomena of electricity, magnetism and light were explained on the basis of the idea of an elastic ether pervading all space.

The phenomena of chemistry were described in terms of Dalton's theory of atoms. The atoms were miniature billiard balls with inertia as their most important attribute. In addition to having mass, they were hard, elastic, impenetrable, indivisible and indestructible. They were assumed to attract or repel each other with so-called central forces. A physical phenomenon was considered as completely explained only when it was described in terms of atoms moving under the influence of central forces.

The great fruitfulness of the mechanistic tendency in physics naturally led to a strong faith in Newton's laws of motion as the ultimate principles governing the physical world. The world was conceived as a machine, as a clockwork ruled by strict causality and therefore completely predetermined. This view was adopted and elaborated by the philosophers of the materialistic school, and it influenced no less the ideas of philosophers in other camps. When the old conceptual framework began to break under the pressure of the development known as modern physics, a number of philosophers of various complexions came to the aid of conservative physicists in defense of the Newtonian scheme.

The growth of physics in the period from about 1895 to the present time is without counterpart in the history of science. The enormous extension of our experimental knowledge and at the same time the complete reconstruction of the conceptual framework from the bottom up which have taken place in the last three or four decades were possible only through the working together of a number of factors. Without attempting a thorough analysis, I shall mention the factors which I believe were of greatest importance. First, the progress in the design and construction of scientific instruments and in the art of experimentation; second, the genius and daring of such theoretical physicists as Planck, Einstein and Bohr; third, the great development of mathematics in the nineteenth century, and fourth, the increasing number of scientific workers and the growing international cooperation in scientific work.

The subject of modern physics may conveniently be discussed, at least in regard to its philosophical implications, under two heads: the theory of relativity and the quantum theory of atomic and molecular structure. The theory of relativity, which was devised to circumvent certain difficulties presented by experiments involving very high velocities, applies primarily to large-scale or cosmological problems, though it is also of fundamental importance on the atomic scale. The quantum theory, which represents our knowledge of atomic phenomena and of radiation, naturally reaches into nearly every branch of physical science; it has, for instance, furnished an extremely valuable clue to the study of the internal constitution of stars.

Since very much has already been written on the theory of relativity and its bearing upon philosophy while very little has yet been written on the philosophical implications of the quantum theory, I shall divide the limited space at my disposal rather unequally between the two theories. I shall treat the theory

of relativity as briefly as possible in order to be able to discuss a little more thoroughly the problems presented by the quantum theory.

In the eighties of last century Michelson and Morley had performed an ingenious experiment the purpose of which was to determine the absolute orbital motion of the earth, *i.e.*, its motion relative to the ether. The experiment gave a negative result: no matter where the earth happened to be in its orbit, there was no indication of any motion of it relative to the ether. This fact, which was corroborated by other experiments, presented exceedingly great difficulties to the theoretical physicists. It was to eliminate these difficulties that, in 1905, Einstein, then only twenty-six years old, proposed his special theory of relativity. If absolute motion can not be measured, Einstein reasoned, then the concept of absolute motion has no meaning and should be abandoned. And guided by the experimental facts, he proceeded to revise completely our concepts of space and time. The supreme importance of the theory which he created lies in the fact that space and time are our most fundamental physical concepts.

To understand the change brought about by Einstein in the concepts of space and time, let us briefly review the positions of Newton and Kant in regard to these concepts. Though Newton professed that "whatever is not derived from phenomena . . . has no place in experimental philosophy," he took over more or less uncritically the contemporary notions of space and time: "Absolute, true and mathematical time flows in virtue of its own nature uniformly and without reference to any external object." Space and time are, so to speak, empty vessels existing independently of their content and of one another. Though Kant recognized the subjective nature of space and time, he regarded them as *a priori* forms of our perception, *i.e.*, as conceptions not derived from experience or subject to revision, but given once and for all. The fundamental spatial concepts such as point, straight line, etc., as well as the axioms of Euclidean geometry he also considered as given *a priori*. In this way he accounted for the absolute certainty which he believed was an attribute of geometry and Newtonian mechanics.

The Kantian view of space and time as *a priori* forms, which really amounted to an acceptance of Newton's absolute space and time, was criticized by Poincaré and others, but the credit for definitely putting space and time in the class with all other physical concepts belongs to Einstein.

In order to define such terms as simultaneity, length, etc., Einstein asked himself: How does the physicist actually determine if two events are simultaneous or not, and how does he actually measure the length of an object? By proceeding in this way, Einstein contributed much to the recognition of the operational character of scientific concepts which has been so clearly emphasized in Bridgman's recent book, "The Logic of Modern Physics."

In the theory of relativity, space and time are fused together into a four-dimensional space-time manifold. The three-dimensional section of this manifold which a certain observer calls space and the one-dimensional section which he calls time are in general different from the space and time of another observer. Space and time are subjective. However, the difference in the spaces and times of two observers depends entirely on their relative motion and not upon their conflicting views on prohibition or the World Court. This relativity of space and time has many striking consequences. Two events which are simultaneous for one observer will in general not be simultaneous for another. If you move relative to another observer, he will

see you flattened up in the direction of your motion and, by closer inspection, will find a subnormal pulse to be another of your symptoms. You, in turn, will see him flattened up and find his pulse to be slow. Unfortunately, it would take enormous relative velocities to observe these curious effects directly. But then, if these effects could be readily observed, they would not be curious, and Newton would have invented the theory of relativity.

Other consequences of the theory, such as the variation of mass with velocity, the existence of an upper limit to velocity, the fusion of the concepts of mass and energy, the modification of the laws of motion, and so on, are of interest chiefly to physicists. I mention them only to indicate how extensive was the revision of the classical conceptions demanded by the theory of relativity.

The theory which has been so far referred to is the so-called special or restricted theory of relativity. It is not necessary to state exactly to what restricted class of motions this theory applies, for in 1915 Einstein succeeded in working out a perfectly general theory which asserts that all motions are relative, *i.e.*, that no matter what the motion of an observer is, his physical experiences may be described by the same fundamental laws. The creation of the general theory of relativity is one of the greatest achievements of the human mind. In commenting upon this theory, the late Dutch mathematical physicist, H. A. Lorentz, said sometime during the war that a hundred years from now this time will be referred to as the time of the creation of the general theory of relativity rather than as the time of the World War. In building up this theory Einstein had to incorporate in it the phenomenon of gravitation. The theory is therefore also a theory of gravitation. He further had to make use of non-Euclidean geometry, the gravitational effects entering in the metric of this geometry. This fusion of gravitational forces with the geometrical properties of space is naturally very desirable, and it gave for the first time an understanding of the well-known fact that weight and mass are proportional. Einstein's most recent work, reported not long ago even in the newspapers, is a successful attempt to incorporate also electromagnetic forces into the general theory.

The departure from Euclidean geometry made possible the solution of a cosmological problem which long had troubled astronomers. According to Newton's theory, the part of the universe which was filled with matter would have to be like an island floating in infinite, empty space. Such a universe would gradually diffuse into the surrounding emptiness. Now, after a slight modification of his theory, Einstein was able to deduce from it a much more satisfactory cosmology, according to which space is more or less spherical in structure, *i.e.*, though unbounded, space has a finite extension, while matter is more or less uniformly distributed over the entire space.

The use of four-dimensional and, still worse, non-Euclidean geometry in the theory of relativity has given rise to much discussion and much misunderstanding. Is space actually non-Euclidean? Or is the use of non-Euclidean geometry simply a mathematical trick which happens to simplify the description of physical phenomena? The former of these two questions is meaningless. Space is neither Euclidean nor non-Euclidean. If we want to call it anything, the most appropriate predicate would be amorphous, as once remarked by Poincaré. What kind of geometry we get depends upon our choice of metric, and we are at liberty to choose whatever metric we please. The second question, if the use of non-Euclidean geometry is

a mathematical trick, must be answered in the affirmative: non-Euclidean geometry is nothing but a conceptual spiderweb which is used by physicists for the sole purpose of simplifying the description. This, however, does not separate Einstein's theory from any other physical theory. All theories are spiderwebs of symbols. The truth of a theory consists in its unique correlation with experience, *i.e.*, a theory is called true if there is a unique correspondence between its statements and the field of facts it is designed to describe. Since all experience is approximative, we can never check this correlation with perfect accuracy. Hence, whenever progress is made in the art of experimentation, we must be prepared to discover imperfections in our theories. There is no such thing as final truth.

The explosion of the Kantian doctrine of synthetic *a priori* judgments broke down the barrier which was supposed to exist between mathematics and physics. The ingenious invention of the so-called implicit definitions by which Hilbert succeeded in making mathematics logically independent of physics does not, of course, change the fact that generically mathematics is rooted in experience. If that were not so, the marvelous usefulness of mathematics would indeed be hard to understand.

Let me close the discussion of the philosophical implications of the theory of relativity with a quotation from Schlick's "Space and Time in Contemporary Physics." He says:

> The importance of these results, in their bearing upon the underlying principles of natural philosophy, is so stupendous that even those who have only a modest interest in physics or the theory of knowledge can not afford to pass them by. One has to delve deep into the history of science to discover theoretical achievements worthy to rank with them. The discovery of Copernicus might suggest itself to the mind; and if Einstein's results do not exert as great an influence on the world-view of people in general as the Copernican revolution, their importance as affecting the purely theoretical picture of the world is correspondingly greater, inasmuch as the deepest foundations of our knowledge concerning physical nature have to be remodeled much more radically than after the discovery of Copernicus.

The theory of relativity is mainly concerned with the framework of space-time; the quantum theory, on the other hand, deals with that which occupies space-time. Being a theory of the structure of atoms and molecules and of radiation, it is as all-embracing as the theory of relativity. While the theory of relativity has stimulated only a rather small number of physical experiments or astronomical observations, the quantum theory has profoundly influenced the work in every physical and chemical institute the world over. As a consequence, though the quantum theory of atomic structure is closely associated with the name of the Danish physicist Niels Bohr, it is less than the theory of relativity the creation of a single man.

In spite of its great usefulness in chemistry, the concept of atoms remained fairly hypothetical throughout the nineteenth century. In fact, towards the end of the century, the great successes obtained by the application of thermodynamics to chemical problems led Ostwald and other chemists to abandon the idea of atoms entirely. However, only a few years later, direct experimental evidence for the existence of atoms was forthcoming. This evidence came only after the discovery of the electron and of radioactivity, so before the existence of atoms was finally established it was known that atoms were not indivisible entities, but that they were made up in part of electrons. Since atoms are electrically neutral while electrons are negatively charged, atoms must also contain positive electric charges. In 1911 Sir Ernest Rutherford made the

extremely important discovery that the entire positive charge, and practically the entire mass, of an atom is concentrated in a space exceedingly much smaller than the size of the atom. The picture which he gave us of an atom resembles greatly our solar system. All the units of positive electricity, protons we now call them, and some of the electrons, are concentrated in the so-called nucleus of the atom. Around the nucleus, the remaining electrons revolve at distances from the nucleus which are very large compared with the diameter of the nucleus. An atom, hence, is largely empty space.

At about the same time, Moseley, a brilliant student of Rutherford's, established the fact through his work on x-ray spectra that the number of net positive charges on the nucleus, and therefore the number of electrons outside the nucleus, is simply equal to the atomic number, *i.e.*, the number listing the element's place in the periodic system of Mendeleeff. It was a fortunate happening that brought Bohr to Manchester shortly after the making of these important discoveries. In 1913 he published his first papers on the constitution of atoms and molecules, thereby laying the foundation to the theory which is dominating physics at the present time. The first nine or ten years of the Bohr theory were years of marvelous triumphs, but gradually it became clear that a deep-going revision was required. The decisive step toward such a revision was taken in 1926 by the young German physicist Heisenberg. Following the lead of de Broglie, Schrödinger, also in 1926, created his wave mechanics, which accomplished essentially the same results as Heisenberg's matrix mechanics. These two theories, while quite different in appearance, were soon found to be mathematically equivalent, and both of them are now parts of a more general quantum mechanics which forms a rational generalization of the original Bohr theory. The years from 1926 to 1928 were, indeed, busy years for the theoretical physicists. The complete overhauling of a theory in a couple of years would have been entirely impossible but for the previous work of mathematicians on matrix algebra and on the theory of differential equations. While rapid progress is still being made in perfecting the new quantum theory, there are strong indications that the main features of the theory have reached a stable form.

Parallel to this theoretical progress and greatly stimulated by it and, in turn, greatly stimulating it, exceedingly important experimental advances have taken place. Two of the most important discoveries of the last decade were made in this country. In 1923 A. H. Compton, now of the University of Chicago, discovered that x-rays suffer a small increase in wave-length when scattered by materials of low density. The wave theory of radiation was unable to account for this phenomenon, but it was readily explained on the basis of the corpuscular theory of light proposed a number of years earlier by Einstein. Thus Compton's discovery made more acute the dilemma concerning the structure of light which had greatly troubled physicists for some time. While the phenomena of diffraction and interference show conclusively that light is a wave motion, other phenomena show equally clearly that light consists of particles! The other discovery, made in 1927, by Davisson and Germer, of the Bell Telephone Laboratories, creates a similar problem concerning the structure of the electron. Up to this time all known electronic phenomena were satisfactorily described by picturing the electrons as small particles. However, Davisson and Germer found that a stream of electrons scattered by a nickel crystal exhibited unmistakable evidence of diffraction and interference. This has been verified by other experiments. In fact, we have now just as compelling reasons for

adopting a wave theory of electrons and protons as those which led to the adoption of the wave theory of light a hundred years ago. But how can light and matter be both particles and waves? We shall return to this question later.

In his attempt to work out a theory for the motion of the extra-nuclear electrons and for the emission of radiation by atoms, Bohr naturally sought guidance from the sciences of mechanics and electrodynamics, which adequately describe the motions of large bodies and the ordinary electromagnetic phenomena. However, it was immediately clear that the ordinary laws of motion, and of electrodynamics, do not hold even approximately for the electrons within an atom. Bohr, therefore, turned to the very radical ideas of discontinuous energy changes invoked by Planck to account for the energy distribution in the so-called black body radiation. These ideas, together with a fundamental law of spectroscopy discovered by Ritz, were shown by Bohr to form a suitable basis for a description of atomic processes. In the original Bohr theory the break with mechanics was not complete. The theory was, therefore, more or less of a patchwork of admittedly provisional character until, guided by Bohr's so-called correspondence principle, Heisenberg achieved its complete emancipation from mechanics, thus making the quantum theory as logically self-contained as ordinary mechanics.

The most basic principle in the quantum theory and that which most sharply distinguishes it from the classical theories and gives it its name is the quantum postulate. According to this principle, an atom does not emit or absorb radiation or exchange energy with other atoms or electrons except during a complete transition from one so-called stationary state to another. The atomic processes are therefore essentially discontinuous in character. Many attempts have been made, first by Planck and most recently by Schrödinger, to alleviate this discontinuity or individuality of atomic processes, but these attempts have all failed.

With the quantum postulate, it has been said, an element of irrationality has been introduced in our description of nature. I believe that it would be more correct to say quite the opposite. For certainly the intelligibility of the world depends largely upon the quantum laws. Knowledge, as we know, depends upon recognition. But recognition depends upon the existence of similarities in the objects of perception. Now if the laws of classical mechanics and electrodynamics held on the atomic scale, we should not have a relatively small number of chemical elements with constant and clear-cut properties such as definite valences and spectra consisting of sharply defined wave-lengths. In fact, if it were not for the quantum laws the physical world would hardly have any structure, and physical knowledge would be impossible. Or better expressed, the quantum theory, as an acknowledgment of a definite structure in atomic phenomena, may be looked upon as a guarantee of the intelligibility of the physical world.

The most important consequences of the quantum postulate are embodied in the principle of uncertainty enunciated by Heisenberg in 1927. The substance of this principle is as simple as its philosophical implications are profound. The principle of uncertainty states that to any mechanical quantity Q corresponds another quantity P in such a way that the product of the uncertainties in our knowledge of Q and P can never be less than the so-called quantum of action or Planck's constant. In other words, the more accurately we have determined the value of Q, the greater must be our ignorance concerning the value of P. For instance, if Q is a vector which determines the position of a particle, P will be its momentum, *i.e.*, the product of the mass and velocity of the particle. Hence the more accurately we have

measured the position of a particle, the less can we know about its velocity. In particular, if the position were given with perfect accuracy, we could have no knowledge whatever about the velocity. Or, conversely, if the velocity of the particle were accurately known, we should be perfectly ignorant about its position. Similarly, even if all practical difficulties interfering with the accuracy of our observations were completely eliminated, we could not know with perfect accuracy the energy of a mechanical system at a given instant. The more accurately the time is fixed, the more uncertain must be our knowledge of the energy. If the time is perfectly accurately fixed, we must be totally ignorant of the value of the energy, and *vice versa*.

The validity of this principle follows from a consideration, in the light of the quantum postulate, of the process of observation. In order that we may observe an event a signal of some sort must reach one of our sense-organs. Let us consider a visual observation, in which case the signal consists of a stream of light quanta or photons. Then, in order that we may observe a certain particle, at least one photon must hit the particle and be deflected by it so as to enter our eye or our microscope or photographic camera. But in being deflected from the particle to be observed, the photon imparts a certain amount of momentum to the particle. Now a simple consideration based upon the theory of the resolving power of optical instruments shows that the more accurately we observe the position of the particle, the less accurately will we know what change in the velocity of the particle has been produced by the rebounding photon. In other words, to the extent that we obtain accurate information of the position of the particle, we lose whatever knowledge we may have had of its velocity. Thus the uncertainty principle follows from these two facts: First, that in any observation we have a coupling or interaction between the object observed and the instrument of observation; and second, that this interaction is governed by the quantum laws and, therefore, can not be reduced below a certain value, which, in the example considered, depends upon the wavelength of the light used.

If the particle which we observe has a very large mass, if it is, for instance, one of the planets, then the impact of the light upon it will produce only an exceedingly small change in its velocity. On the other hand, if the particle should be an electron moving around an atomic nucleus in a certain stationary state of an atom, then an observation of the instantaneous position of the electron would bring the atom entirely out of its stationary state, thus making it impossible to observe more than one point of the electronic orbit.

Our knowledge of the physical world is thus restricted not only by imperfections in our instruments and methods of measurement, which we may hope to remove to a greater and greater degree, but also by unsurmountable barriers set up by the quantum structure of the universe, *i.e.*, by the very structure which makes the world intelligible.

Now if all physical knowledge is thus limited by the uncertainty principle, then the possibility of a space-time description of physical phenomena must be correspondingly restricted. If only one point can be observed of the orbit of an electron moving in an atom in a stationary state, then the very idea of orbit obviously loses its meaning. No space-time description of atomic transition processes, and hence no visualization, is possible. Thus the kinematics of the quantum theory must be radically different from that of ordinary mechanics. It has been claimed that even if an exact space-time description of atomic processes is impossible, still each electron must obviously have a definite position at any moment. But this demand for what Whitehead calls simple loca-

tion is no more valid than the belief in absolute motion after the adoption of the theory of relativity.

The faith of the old physics in simple location is called by Whitehead the fallacy of misplaced concreteness. The recognition of this fallacy is obviously of the utmost importance for the general theory of knowledge.

The renunciation of the belief in simple location has an interesting consequence. In his "Allgemeine Erkenntnislehre" Schlick sets up the following criterion of reality: real is everything which must be conceived of as existing at a definite time. Now if no space-time description of the atomic processes is possible, these processes would be deemed unreal according to Schlick. His criterion of reality, which otherwise seems too broad, hence needs revision if real existence is to be attributed to the electrons within the atoms.

The limitation imposed upon any space-time description by the principle of uncertainty has completely removed the dilemma concerning the structure of light and matter. Both the particle picture and the wave picture have only a limited validity and, as Bohr has shown, their limitations are such as to exclude any contradiction between them. To the extent that a space-time description is possible, both concepts are perfectly equivalent.

The most interesting philosophical implication of the principle of uncertainty is its bearing upon the principle of causality. This latter principle, which was so strongly supported by classical physics, has come to be regarded as almost self-evident like the axioms of Euclidean geometry. The traditional belief in the exalted position of the principle of causality is well exemplified by the following statement by the German mathematical physicist G. Mie. He writes in the first volume of Müller-Pouillet's "Lehrbuch der Physik," published in 1929:

> Thus we may compare the entire picture of the world which physics has constructed with a network of artfully woven threads, of which causality is the cohesive force. If the connection would be severed in a single mask, the entire weave would come apart. To sacrifice even the smallest iota of the principle of causality would mean to give up physics.

Now the principle of causality states that if an isolated part of the universe were known with perfect accuracy at a given instant, then it should be possible, at least in principle, to predict any future event within this part of the world. But according to the principle of uncertainty, the state of no part of the universe can be known with perfect accuracy. Not even the state of a single atom, or even of a single electron, can be fully known. In fact, if half of the quantities required for specifying the state of a given system were known with perfect accuracy, we should be completely ignorant of the values of the other half of the required quantities. The principle of causality, as formulated, is therefore not valid. The belief in strict or rigorous causality must be given up. Of course, it may be maintained that the world may well be ruled by determinism and that the principle of causality may well hold even if our limitations are such that we can not accurately check this determinism. But in this interpretation the principle of causality would be meaningless. For a statement ceases to have meaning when it is recognized that no criterion exists for testing its validity.

It is necessary to analyze the matter a little more closely. The principle of causality applies to isolated systems, but whenever a system is being observed it is no more an isolated system. Causality and observation thus mutually exclude one another. Bohr, to whom our present understanding of the uncertainty principle is largely due, speaks about a fundamental complementarity between causality and the possibility of observation and hence of space-time description. The principle of causality is implied whenever we make use of the laws of the conservation of energy and momen-

tum, and in such cases a space-time description is out of question. The claim of causality may also be said to be satisfied as long as we describe a phenomenon by means of the abstract mathematical machinery of the quantum theory, but the equations contain the time and the space coordinates in a purely formal manner and furnish no space-time description. Such a description, obtained when the results of the computations are given a physical interpretation, always implies observation and hence a break in the causal chain.

It is an interesting feature of the quantum theory, first recognized by Born, that its statements, when interpreted physically, must be considered as having only statistical significance. In this regard the laws of the quantum theory are much like the laws of thermodynamics or like Mendel's laws in genetics. A statistical law gives only probabilities and average values. The accuracy of its predictions depends entirely upon the number of individuals in the group considered and upon the length of time the group is observed.

Now the laws which are found to hold for matter in bulk, in particular the laws of ordinary mechanics and electrodynamics, must evidently be regarded, in spite of the theory of emergent evolution, as consequences on the laws holding for single atoms or for small groups of atoms. It seems, therefore, that all known physical laws are of statistical nature. We may, therefore, well raise the question: Is statistical truth the only kind of truth which we may strive for? And we may ask: Are statistical laws possible without primary laws? It would seem that any statistical regularity must depend upon some sort of similarity in the behavior of the individuals. If this similarity in behavior is not a primary law it must presumably be statistical, but then it would depend upon some more fundamental regularity, which in turn might be either statistical or primary, and so on. We shall not attempt to answer these questions. It may well be that the very distinction between primary and statistical law is a fallacy.

The application of the laws of the quantum theory to physical problems is often very difficult. Not only do we have a choice between two space-time pictures, that of a particle and that of a wave, whose limitations must be constantly kept in mind, but there is, in addition, a wide ambiguity as to the differentiation between the object to be observed and the instrument of observation. Thus, in the idealized experiment described above in which the position of an electron is determined by observing the light it scatters, we may consider either the electron alone, or the electron and the light, or the electron, the light and the microscope as the object to be observed. Or we might even include our eye and part of our nervous system. In principle, it makes no difference how we delimit the object, but of course the mathematical machinery of the quantum theory must be applied in accordance with the choice we make. Obviously, we need to develop new concepts and mental habits which conform to the requirements of the quantum theory, for we are continually apt to be deceived by the traditional scientific thought with its union of causality and space-time description.

The strange implications of the theory of relativity and of the quantum theory may be disregarded by many experimental physicists who deal with slow motions and with large-scale phenomena, but for the epistemologist these implications are of the utmost importance. The theory of relativity has already had a profound influence upon contemporary scientific thought, and it is clear that Bohr's conception of a complementarity between space-time description and causality, based upon Heisenberg's principle of uncertainty, will have a central place in any future theory of knowledge.

THE GASEOUS EXPLOSIVE REACTION[1]

By Professor F. W. STEVENS

PHYSICIST, UNITED STATES BUREAU OF STANDARDS

THE extensive application of the gaseous explosive reaction as a source of power in internal combustion engines has given every one at least some acquaintance with it in its present popular rôle; for in this rôle it occupies a large part of the world's stage, proclaiming in modern noisy, spectacular fashion to crowded houses its latest contribution to the secondary environment within which, above, below and all around, human life is rapidly enclosing itself.

This particular application of one of the commonest forms of molecular transformation to be met with—a transformation wholly confined to the gaseous state at the high temperature of flame—has been from earliest times perhaps more intimately associated with human life than any other of nature's forces.

The longest well-developed road we know is that leading from the primitive engineer who first built his fire at the mouth of a cave to gain the advantage of its heat in the bodily comfort of warmth, to the modern engineer who now builds it within the engine's cylinder to gain the advantage of its heat in the control and direction of power. Yet the primitive engineer in building his fire was concerned with the same general technical problems as the modern engineer: Both selected their fuel from nature's store with care based on trial and experience; both were concerned with the problem of ignition and with its position, relative to the fuel, where it would be most effective; both estimated, then apportioned, the amount of fuel to meet the required end, and both were particularly concerned in controlling the period of its transformation.

If in general the broad technical problems that have so far arisen in the various applications made of the flame reaction have changed but little over this long period of development, the changes that its multiplying applications have wrought in the environment of those devising and using them, together with the changes compelled by the reaction of that modified environment on intellectual development and outlook, form a record of basic human interest. Such a record of any line of development exhibits the interrelation between what is termed human progress and the products, material and intellectual, of that progress that provide the equipment necessary for effecting the next advance.

> Whoever has followed the history of a single science finds in its development a clue to the understanding of the oldest and commonest processes of all knowledge and cognizance.[2]

> Historical studies are of fundamental importance in connection with the effort to advance scientific knowledge in any line. It is from such studies that we became acquainted with other problems, other possible assumptions, other viewpoints whose birth, growth, change and decay were connected with the conditions under which the processes then studied took place. Under the influence of other facts which once occupied the front of the stage, there arose other concepts than those today in vogue; from these we may observe that ever new problems arose to demand solution. If we accustom ourselves to consider every concept simply as a means to a definite end, we likewise accustom ourselves in any particular case to tolerate in our own mode of thinking those changes that the facts seem to require.[3]

That part of the development of knowledge pertaining to the flame that

[1] Publication approved by the Director of the Bureau of Standards of the U. S. Department of Commerce.

[2] Nietzsche.

[3] E. Mach.

is most intimately connected with its present extensive application as a source of power, is of rather recent acquisition —paralleling closely industrial development that is dependent on the efficient use of power. It might be mentioned, however, that the long slow development previous to the industrial era is by no means devoid either of technical or of human interest. The specialist in folklore finds the flame intimately connected with the life of the home, while the traditions of alchemy still abundantly persist. With the passing of the hearthstone, passed many of the traditions, industries and influences of home life—the essential matrix that insured the solidarity of the older state. Besides, it was during this long period of companionate intimacy with the family that the flame firmly established itself as a powerful mystic symbol of life. It inspired contemplation on the ancient altar, it still provokes humility and reverence on the modern one. These human reactions may not be ignored in modern research, for, given time enough, the concepts born of the science of any period ultimately become a lore.

Diffusion Flames

The realization of the fact that the common flame—no matter what may have been the crude form of the fuel used—burned only gas, developed with extreme slowness; but when fully realized, quick advantage was taken of it in the manufacture and piping of "distilled coal" from a central works. This gas was at first largely produced and consumed for lighting purposes in fishtail burners. Like the primitive flame that it was, the flame in this case depended for its support on the mutual rate of diffusion between the fuel-gas and the air. Between the layer of pure gas on the one hand and pure air on the other, there existed regions of every possible mixture ratio of fuel-gas and air. Not all these mixture ratios would support a flame reaction and only one of them would support the reaction without loss to either reacting component. The economic possibility occurred to Bunsen of effecting the complete diffusion of the active gases, before ignition, in any desired mixture of gas and air or of gas and oxygen. The original simple device developed to secure this advantage—the Bunsen burner—made a new and highly efficient flame form possible while incidentally solving the smoke prevention problem. Numerous modifications of Bunsen's device suitable to different industrial purposes have rapidly followed. In magnitude this application by industry of the continuous gaseous explosive reaction rivals its application as a source of power in the gas engine.

The Zone of Explosive Reaction

When a homogenous mixture of explosive gases is fed through a tube at a constant volume rate of flow and ignited, the characteristic form assumed by the flame is no longer diffused but is confined to a thin, sharply defined stratum or zone within which the explosive transformation of the gases takes place. The reaction conditions automatically maintained by the continuous uniform flow of the homogenous mixture of explosive gases is therefore constant. Fig. 1 (p. 561) is a photograph of the stationary explosive reaction zone formed above the burner tube. Fig. 2 is a schematic diagram of it. This device in its most refined form and accurate manipulation provided the first opportunity for studying at least the gross mechanism of the gaseous explosive process. Gouy (1879), in carrying out his photometric investigations of colored flames, using a modified Bunsen burner, realized that this stationary figure of the reaction zone so closely approaching a perfect cone could, under

favorable conditions, be analyzed in terms of the relative movement between zone and active gases supporting it. He found that if u was the uniform linear rate of flow of a filament of the explosive gas issuing from the tube and entering the zone at an angle α, then the component of u normal to the surface of the zone would just balance the linear rate of propagation of the zone within the gases. He further found that any change in the velocity of u was followed by such an automatic readjustment of the symmetrical conical figure, and hence of the angle α, that the linear rate of propagation of the reaction zone for a given explosive mixture remained constant. Gouy's results may be stated as follows: *The linear rate of propagation of the reaction zone relative to a homogeneous mixture of explosive gases is constant at constant pressure and independent of the mass movement of the active gases supporting the zone.* Gouy's experimental results, dealing with the gross mechanism of the gaseous explosive reaction at constant pressure, were, as stated, incidental to his investigation of colored flames. They have remained for a long time obscure.

In the meantime unusual interest and activity developed in the study of the gaseous explosive reaction under constant volume conditions. Under these conditions the observed rate of displacement of the zone in space is far from constant. The initial pressure and temperature of the active gases passing the reaction zone during the progress of the explosion is likewise variable; also the essential factor—the mass movement of the active gases supporting the zone, determinate, at least approximately, by Gouy's method, is indeterminate under constant volume conditions. As a consequence, *the linear rate of propagation of the reaction zone relative to the active gases carrying it, i.e., their linear rate of transformation, can not be determined under constant volume conditions, because the mass movement of the gases carrying the zone is indeterminate.*

But the study of gaseous explosions in closed containers, nevertheless, led to important results. In 1883 Berthelot and Vieille announced the discovery of a new gross mechanism of the explosive reaction. This they designated as the explosive wave.

> As soon as the compression of the unburned layer of gases in the container becomes so great that self-ignition follows, the resulting extraordinary powerful compression wave is propagated with very great velocity and with simultaneous ignition; *i.e.*, we have the spontaneous development of the explosive wave.[4]

The pressure within the wave is constant; its rate of propagation is constant and characteristic for each mixture ratio; it is independent of initial pressure and of the container. For purposes of study, the wave has usually been incited in explosive mixtures by the development within long cylindrical containers of those pressure-temperature conditions necessary to its formation and continuation. It was discovered in connection with the normal burning reaction. It is not, however, dependent on this preliminary stage. Any means of producing in the explosive gaseous fluid a compression wave intense enough to ignite the gases will incite the explosive wave form of reaction in those mixtures able to support it. The propagation of the explosive wave is usually looked upon as a purely hydrodynamic process into which the molecular transformation enters only as a thermodynamic factor, the heat of reaction. Nernst has expressed the opinion that molecular theoretical consideration introduced to explain explosive wave phenomena are as much out of place as they would be for the treatment of acoustics. Nevertheless the modern theory and mechanism

[4] Nernst.

involved in the kinetics of chain reactions seem to offer quite as favorable an explanation of the phenomena as purely hydromechanical considerations. In reference to the various special theories that arise from time to time, resulting from studies of special reaction forms, it should be appreciated that the different reaction forms that the same gaseous molecular transformation may assume all lead to the same final equilibrium condition, K, for the same final temperature and pressure. The transition from one form to another is abrupt and outwardly definitely marked. It is assumed, however, since each of these forms leads to the same end point, that the ultimate microprocesses (if "ultimates" exist) in each of them are the same; yet no satisfactory theory and mechanism describing these microprocesses and at the same time accounting for the abrupt changes in reaction rates that characterize the different forms have as yet appeared.

As far as industrial applications of the reaction as a source of power are concerned, experience shows that only its normal burning form is applicable. Both in engine design and in preparation of fuel it is sought in practice to confine the reaction strictly to its normal burning form; yet the study of this important form has received far less attention than that of the slow reaction below ignition temperature and much less consideration than the explosive wave (detonation) or even its electrochemical form occurring in the gas cell.

With very few exceptions, all the studies of the normal burning gaseous reaction have been made under conditions of constant volume. A survey of the great number of such studies dealing with the behavior of the reaction zone will show, however, that the observed time-displacement of the zone in space has erroneously been considered its rate of propagation within the gases. The rate of displacement of the zone in space is the sum of its rate of propagation relative to the gases plus the rate of mass movement of the gases carrying it. In the case of the reaction at constant pressure, the rate of mass movement of the gases is always numerically much greater than the rate of propagation and this is true also for the initial stages of the reaction under conditions of constant volume. Perhaps the necessary distinction between the rate of displacement of the reaction zone in space and its rate of propagation relative to the active gases carrying it may be made clearer by considering the case of a man walking at uniform rate along a moving train of box-cars. In order to find his rate of progress (propagation) relative to the train (gases) from his observed rate of displacement in space, the simultaneous movement of the train (gases) must be known. The train (gases) may slow down, go faster, stop or back up (it does all this and worse in a few thousandths of a second under constant volume conditions), while the movement of the man (zone) relative to the train (gases) remains constant. Helmholtz and Kundt pointed out this error in the earlier results published on the behavior of the normal burning reaction zone, and at their instigation Michelson (1889) carried out a set of studies to determine the normal rate of flame propagation in mixtures of explosive gases. Michelson found for the normal burning reaction zone, as did Berthelot for the explosive wave, that each explosive mixture, at constant pressure, had its own characteristic rate of propagation—the explosive wave values for the same reaction being some thousand times higher than the corresponding values of the normal burning zone. Michelson plotted the results he obtained, expressing velocities as ordinates and the volumetric mixture ratios as abscissae. By so doing he found that the resulting graphs in all cases indi-

cated a smooth curve with maximum at or near the velocity corresponding to equivalent proportions of the reacting components. The most complete and definite set of results obtained by him were those for the explosive reaction of carbon monoxide and oxygen. The explosive reaction of these gases saturated at room temperature with water vapor, is relatively slow, while the actinic property of the reaction zone is most favorable for securing photographic records of it.

It was Michelson's coordinate figure expressing the experimental relation between the rate of propagation of the reaction zone measured relative to the active gases (their linear rate of transformation) and the volumetric mixture ratios of those gases that led the writer to suspect a possible statistical relation between the linear rate of propagation of the zone within the gases and their molecular concentrations—a relation analogous to that offered by Arrhenius between the rate of molecular transformation, V, and the partial pressures of the active gases. $V = k_1[A]^{n_1}[B]^{n_2}[C]^{n_3}$ .... is Arrhenius's expression for the rate of molecular transformation in one direction of a gaseous system, where [A], [B], etc., are the partial pressures of the various active gases, n_1, n_2, etc., their respective coefficients in the stoichiometric equation written for complete reaction; $n_1 + n_2 +$ etc. is the assumed reaction order. k_1 is a proportionality factor termed a velocity coefficient. In the case of the gaseous reaction $2CO + O_2 \rightarrow K$, Arrhenius's generalized expression becomes $V = k_1[CO]^2[O_2]$. In this expression for molecular transformation, the writer substituted for V the experimental values for the linear rate of propagation, s (transformation), found by Michelson, and for the bracketed expressions, the partial pressures of CO and O_2 corresponding to s. At constant pressure the concentrations of the active gases entering the zone remain constant; hence s should remain constant, as it does. $k_1 = \frac{s}{[CO]^2[O_2]}$ states how much greater the numerical value of the linear rate of propagation is than the numerical value of $\Gamma = [CO]^2[O_2]$ giving the probable rate of impacts in an assumed trimolecular order, $2CO + O_2$, finally resulting in an equilibrium condition, $K = \frac{[CO_2]^2}{[CO]^2[O_2]}$. The equation $s = k_1[CO]^2[O_2]$ has its maximum value when the partial pressure of $CO = .667$ and $O_2 = .333$. This is close to the experimental value found by Michelson. Using all of Michelson's experimental values, it was further found that k_1 remained fairly constant. Much closer agreement was later found by repeating and greatly extending his experimental studies. In so doing, however, a number of disadvantages not easily overcome were revealed in the burner method. In only those cases where the stationary form of the reaction zone approached closely a symmetrical cone was the agreement found satisfactory. The distribution of flow velocities over the cross-section of the tube is, in most cases, far from uniform, while the assumption that their rate and direction of flow after leaving the aperture of the tube remains parallel to its axis will not hold; especially is this found to be the case where high flow velocities through the tube are necessary to balance the high rates of propagation of the reaction zone met with in many gaseous explosive mixtures. The method has very narrow limitations; it is only approximate in those cases where an assumption of uniform flow both within and without the burner tube may not be greatly in error. Fig. 7 shows the close agreement between observed and calculated values of s in this reaction when some of the

disadvantages of the burner method have been overcome.

The Spherical Bomb of Constant Volume with Central Ignition

In seeking some means whereby the actual rate of propagation of the zone relative to the active gases (their linear rate of transformation in a gaseous system) could be distinguished from the simultaneous mass movement of the gases, a number of controlling and directive principles already well established played a determining part. Chief among these were two thermodynamic methods, one theoretical, the other experimental, but both offering interesting suggestions as to the behavior of the reaction zone in explosive transformations. The theoretical mechanism made use of by van't Hoff and others in computing the maximum work of a gaseous transformation employs three imaginary zones or compartments corresponding to three important stages in the reaction over which by a cycle process the maximum work of the transformation is computed. This imagined process involves the concept of a continuous uniform reaction maintained in the reaction chamber by supplying it with initial active components *at the same uniform rate* at which the reaction (equilibrium) products were removed to the equilibrium zone. Now the gaseous explosive reaction automatically falls into the same three well-marked zones and at constant pressure actually executes the imagined process described by van't Hoff of supplying its reaction zone with initial active components at the same constant rate that the reaction (equilibrium) products are removed from it. The other thermodynamic method involving the behavior of the reaction zone, was a purely experimental one in which it is evident that the high degree of accuracy attained during the last twenty years by its use depends on the inherent

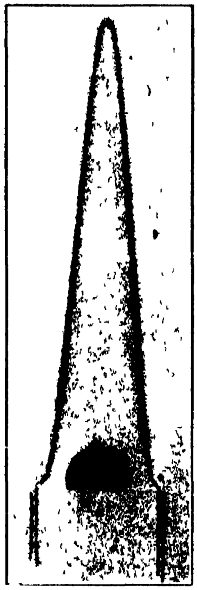


Fig. 1

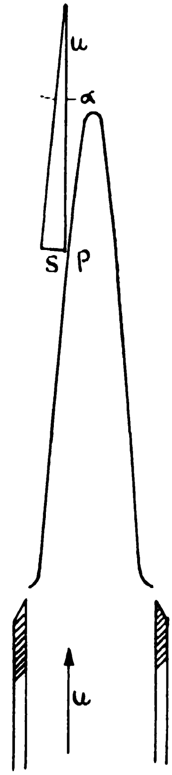


Fig. 2

characteristics of the reaction zone in effecting the transformation of a gaseous system. The new principle introduced with so much advantage in these thermodynamic studies is the old principle of symmetry. Langen, an automotive engineer, engaged on studies of the gas engine with the ultimate purpose in view of establishing for it a rational thermodynamic cycle of reference, realized clearly that the movement of the normal burning reaction zone as observed in space was made up at all times of the rate at which the zone propagated itself relative to the active gases carrying it and the mass movement of the gases themselves. Realizing this he further saw that if the explosive reaction in homogeneous gases originated at the center of a spherical bomb of constant volume, then the reaction zone together with the hydrodynamic disturbances set

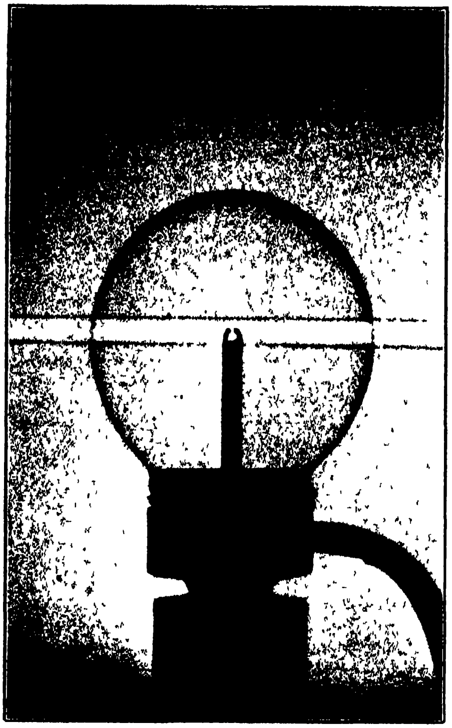


FIG. 3

up in the homogeneous fluid at the same point must all maintain, during the transformation, positions concentrically symmetrical with the ignition point and with the spherical bomb. In this way the heat losses, large and indeterminate in the engine cylinder or in any other form of container—during the progress of the explosion would, by this application of the principle of symmetry, be reduced to unavoidable losses due only to radiation. Such insight on the part of Langen, having regard both to the dynamics of the engine's fluid and to the consequent favorable symmetry of all of the processes occurring in it, has developed into an instrument of high precision—an instrument and method inspired by the demands of industry, serving most efficiently both practical and theoretical ends.

A specially high value must be attached to the explosion method, since, by suitable variations of the experimental conditions, it enables both the specific heats and the equilibrium constant to be determined.[5]

THE SPHERICAL BOMB OF CONSTANT PRESSURE WITH CENTRAL IGNITION

In the light of historical development—from the lead of the well-traveled road—it would be difficult to escape the suggestion so evident in the constant pressure method of Gouy-Michelson, in the theoretical vision of van't Hoff's cycle and in the constant volume method and device of Langen, that, if a volume of homogeneous explosive gases at rest and without diffusion could exist temporarily in space, a reaction zone originating at a point within would propagate itself in the homogeneous gases at a constant rate in all directions; it would be an expanding sphere enclosing the reaction (equilibrium) products. The idea suggested itself that a close approach to this ideally favorable but practically unattainable condition could be to a fair degree realized by holding temporarily the explosive gaseous mix-

[5] Nernst.

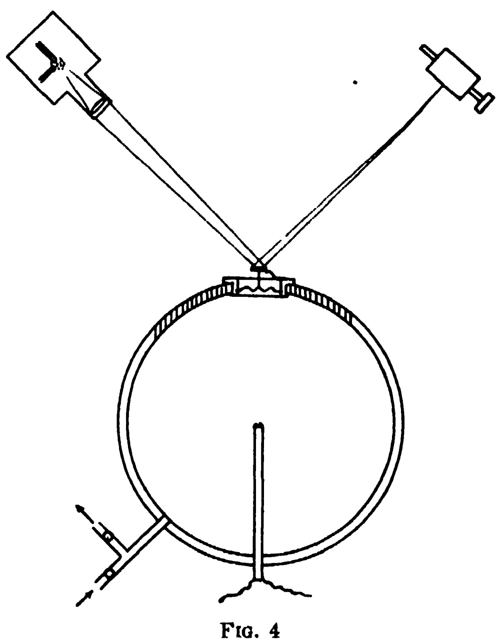


FIG. 4

ture within a soap film container and firing it from the center. Fig. 3 is a photograph of such a container holding temporarily an explosive mixture of carbon monoxide and oxygen. Fig. 4 is a schematic figure of Langen's spherical constant volume bomb with central ignition. Fig. 5 is a photographic time-volume record of the reaction that followed ignition of the gases in the soap film bomb Fig. 6 is a time-pressure record of the reaction, obtained with a Pier manometer, that followed ignition in Lange's spherical constant volume bomb. These two sets of figures, the one expressing the initial and final volumes at constant pressure, the other expressing the initial and final pressures at constant volume, are thermodynamically related as expressed in the gas law, $pv = nRT$ The final pressure corresponds to the reaction constant K_v; the final volume, to the reaction constant K_p

Fig 5 permits the sought-for distinction to be made between the actual rate of propagation, s, of the reaction zone and the rate of mass movement of the active gases carrying it The time-displacement trace of the zone on the moving photographic film is a right line. The speed of the film and the rate of displacement of the zone at right angles to each other were constant; hence the inclination of the zone trace on the film gives the rate of displacement of the zone in space, s'. The initial volume of the explosive gases whose transformation is here considered and whose time-volume change is automatically recorded in Fig. 5 is the volume of a sphere whose initial diameter is 2r—the horizontal diameter of the bubble passing through the point of ignition. The bubble itself is not a sphere, but the reaction zone originating at the point of ignition is a sphere and remains so during the transformation of the gases. The volume of this expanding sphere at the instant all of the gases of the initial sphere, 2r,

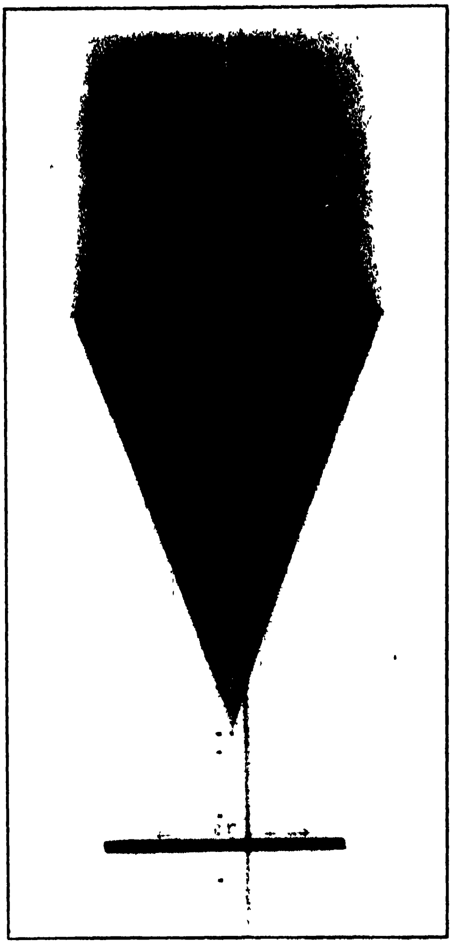


FIG 5

have been transformed, is given by its final diameter, 2r', recorded in the photographic time-volume figure From these dimensions the rate of propagation of the zone relative to the active gases (their linear rate of transformation) may be found. It is $s = s' \frac{r^3}{r'^3}$. The rate of mass movement of the active gases away from the ignition point is, for the condition of constant pressure here described, $s' - s$

The simple bubble device, functioning as a transparent bomb of constant pressure, is the complement of the bomb of constant volume; it duplicates all of the thermodynamic possibilities of that

bomb, dispenses with a manometer, and avoids the unfavorable violent disturbances of the gaseous fluid inseparable from the explosive reaction at constant volume. Being transparent, it provides in addition an accurate method for determining, under standard conditions, the rate of propagation of the reaction zone relative to the active gases. For this purpose it is applicable to a very wide range of reaction velocities below the velocity of sound in the gases. With this device the empirical statistical relation, indicated in Michelson's published results, connecting the rate of propagation of the zone with the concentration composition of the active gases, was tested out: $s = s'\frac{r^3}{r'^3} = k_1[CO]^2[O_2]$. The results that were obtained are shown in the coordinate Fig. 7. Experimental values are represented in the figure by filled circles. Open circles and the continuous link mark the locus of the equation, $s = 691[CO]^2[O_2]$. The constant, 691, is the average value of $k = \frac{s}{[CO^2][O_2]}$ over the range of mixture ratios that would support a reaction zone. The agreement here between observed and calculated values is seen to be close.

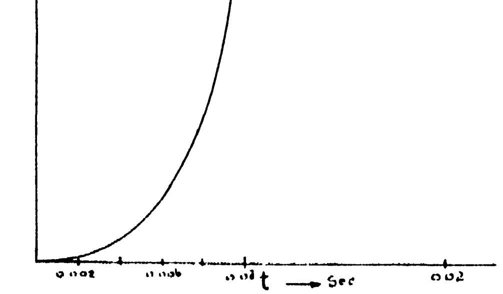


FIG. 6

The stoichiometric equation expressing the equality of masses between the initial components and the reaction products, together with the reaction heat of the transformation, provide the fundamental thermodynamic factors available to the engineer. In the value of K they express for any given condition of temperature and pressure the reaction constant—the essential factor in determining the maximum work of the explosive reaction, A (van't Hoff's reaction cycle). In its simplest form, this may be expressed as $A = RT \ln K$ Should a relationship of the same factors express also the rate of energy liberation in the same gaseous explosive charge, their practical utility would be much extended as well as their theoretical significance. During the last few years the relationship shown in the coordinate Fig 7 has been tested in the case of a great many other gaseous explosive combinations; in all of these cases the relationship between rate of propagation and the concentrations of the active components was found to hold wherever the stoichiometric equation could be written for the completed reaction. The details of these studies and their specific results can not be given here. They involve not only simple gases such as the example given, but fuels of complex composition also, made up of known components in known proportions; and the effect of inert gases. Reactions have also been studied over wide ranges of different constant pressures and the effect of pressure on the rate of propagation of the reaction zone and the rate of molecular (energy) transformation within it, determined. When the reaction takes place at constant volume the unburned active gases may be progressively subjected to pressures varying, say, from one to ten or

more atmospheres in a very small fraction of a second. The reaction period is so short that the instant effect of the rapidly increasing pressure on the rate of propagation of the reaction zone and on the rate of molecular transformation within it becomes practically impossible to determine. But by the constant pressure method described, the instant pressure corresponding to any stage in the progress of the constant volume reaction may be duplicated and indefinitely maintained so that the effect of the pressure on the rate of propagation of the reaction zone for all mixture ratios of the given fuel that will ignite may be readily measured. The results of these special studies, carried out at the Bureau of Standards at the request of and with the financial support of the National Advisory Committee for Aeronautics, may be found in the committee's Technical Reports.

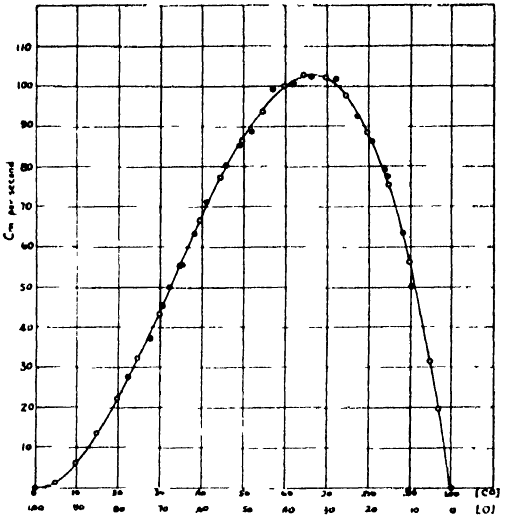
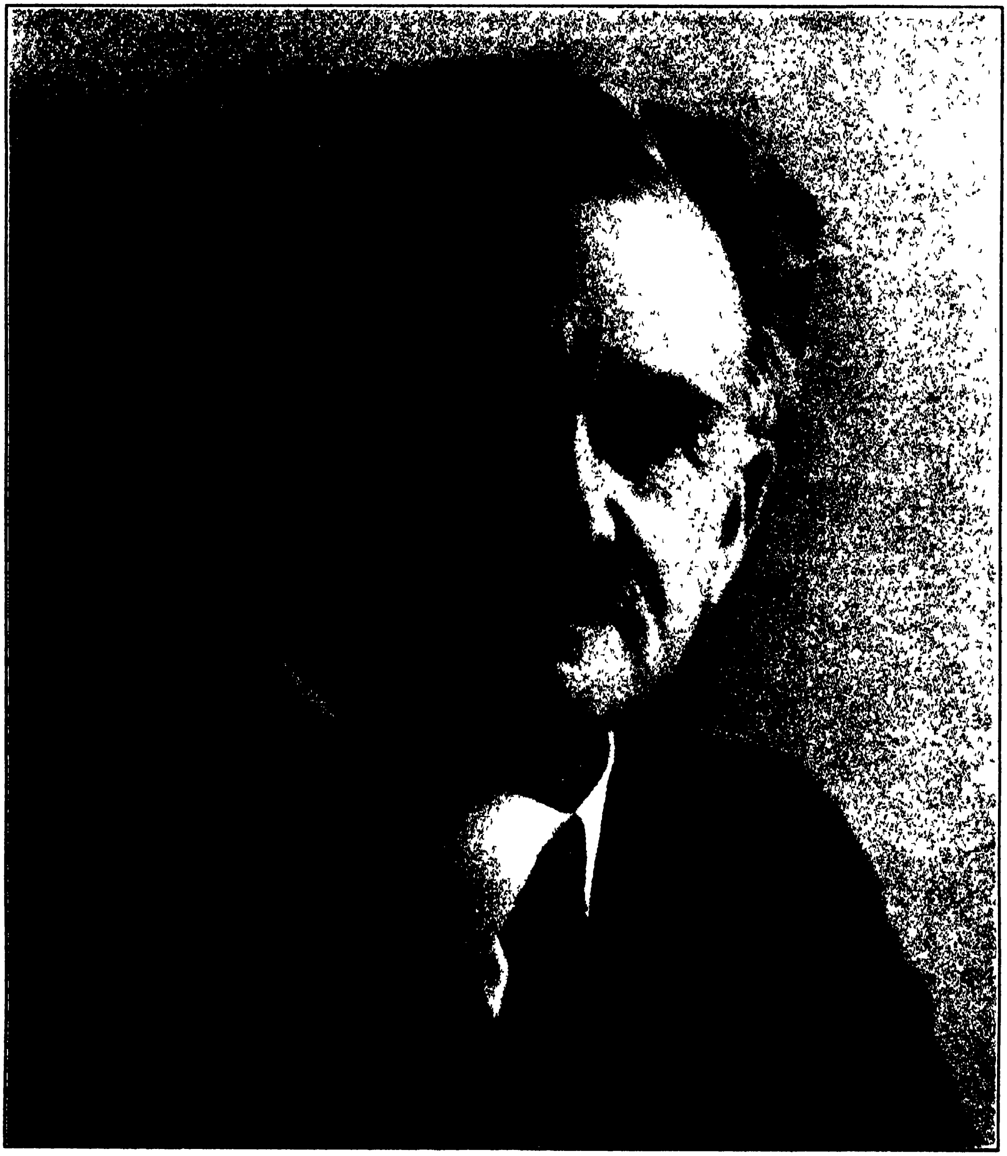


FIG.



ALBERT ABRAHAM MICHELSON

LATE DISTINGUISHED SERVICE PROFESSOR AND HEAD OF THE DEPARTMENT OF PHYSICS OF THE UNIVERSITY OF CHICAGO, WHO DIED IN PASADENA ON MAY 9.

THE PROGRESS OF SCIENCE

THE FRANKLIN MEDAL AWARDS OF THE FRANKLIN INSTITUTE

THE Franklin Medal, the highest award in the gift of The Franklin Institute, is awarded annually to those workers in physical science or technology, without regard to country, whose efforts, in the opinion of the institute, acting through its committee on science and the arts, have done most to advance a knowledge of physical science or its applications

This year two Franklin Medals have been awarded and were presented to the recipients at the Medal Day Exercises at The Franklin Institute on the afternoon of Wednesday, May 20.

One of these awards was presented to Sir James Hopwood Jeans, of London, England, in recognition of his many fruitful contributions to mathematical physics, especially in the realms of the dynamical theory of gases and the theories of radiation, of his challenging explanations of astronomical problems and of his illuminating expositions of modern scientific ideas.

Sir James Jeans was born in London in 1877, was educated at Trinity College, Cambridge, where he was second wrangler in 1898 and Smith's prizeman in 1900. Mention of some of the positions he has held will show the influence he has been in the field of scientific education. He was professor of applied mathematics at Princeton University from 1905 to 1909, Stokes lecturer at Cambridge from 1910 to 1912, Halley lecturer at Oxford in 1922, associate at Mt. Wilson Observatory in 1928 and secretary of the Royal Society

He has been the recipient of many honors—a Royal Medal from the Royal Society in 1919, the Gold Medal of the Royal Astronomical Society in 1922 He is a fellow of the Royal Society and of Trinity College and was knighted in 1928.

He has been a leader in the advances that have been made in the fields of the physical sciences, notably in astronomy. That this is so may be seen by a consideration of the many books that he has published: "The Dynamical Theory of Gases" in 1904, "Theoretical Mechanics" in 1908, "The Mathematical Theory of Electricity and Magnetism" in 1908, "Radiation and the Quantum Theory" in 1914, "Problems of Cosmogony and Stellar Dynamics" in 1919, "Atomicity and Quanta" in 1926, "Astronomy and Cosmogony" in 1928, "The Universe Around Us" in 1929, "The Mysterious Universe" in 1930 and "The Stars in Their Courses" in 1931

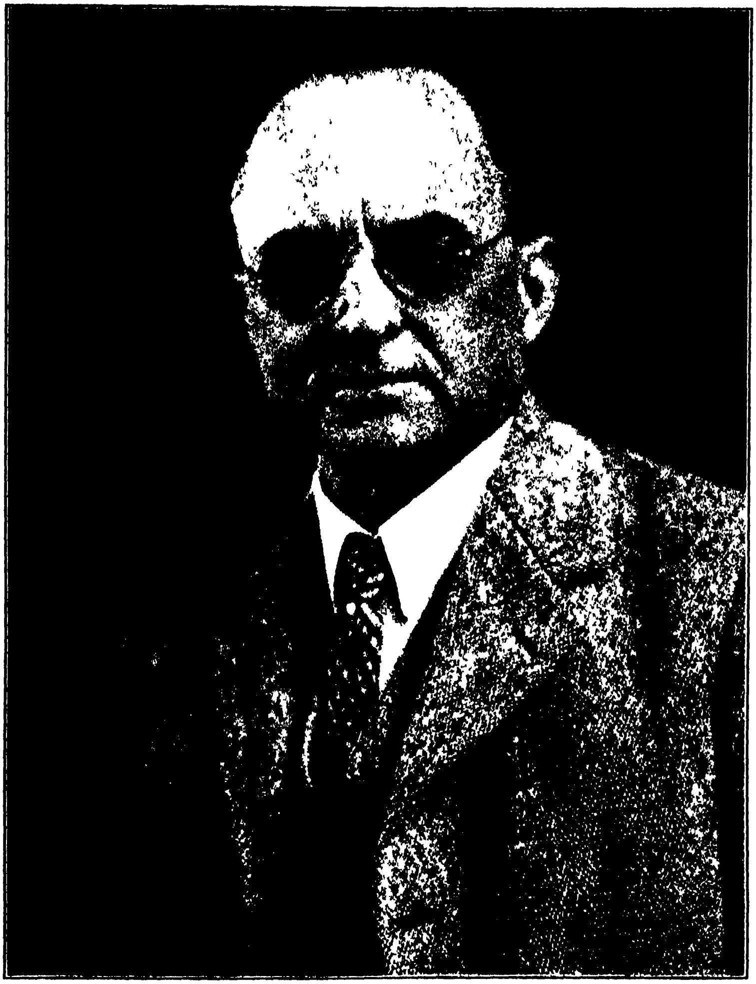
While a number of these books are highly technical and can be read with full understanding only by those having a scientific education the later books are of a more popular character. This is especially true of "The Stars in Their Courses," which is an expansion of a series of radio talks given through the British Broadcasting Company. The book puts in an attractive and readily understood fashion the story of what constitutes the universe as it is understood by one who has made the subject a lifelong study. Sir James has made many contributions to the growth of science, as is shown in his many papers published in scientific journals.

Another medalist for 1931, to whom the Franklin Medal was awarded, is Dr. Willis Rodney Whitney, of Schenectady, New York, in recognition of his valuable contributions to industrial chemistry and of his signal success as organizer and director of the greatly productive research laboratory of the General Electric Company, a success due in large part to his appreciation of the potential value of pure research in

SIR JAMES HOPWOOD JEANS

invention and industry, to his judgment of men and to his generosity in dealing with them

Dr. Whitney's birthplace was Jamestown, New York, in 1868. He was graduated from the Massachusetts Institute of Technology in 1890 with the degree of S.B. and received the degree of Ph.D. from the University of Leipzig in 1896. From 1890 to 1904 he was engaged in educational work, serving as an investigator and a teacher in the department of chemistry of the Massachusetts Institute of Technology, where he advanced by regular steps from assistant instructor to assistant professor and now holds the position of non-resident professor of theoretical chemistry in that institution. His present position is that of director of the Research Laboratory of the General Electric Company, at Schenectady, New York. He received the honorary degree of Sc D. from Union University and that of Ch D. from the University of Pittsburgh In 1916 Dr. Whitney was awarded the Willard Gibbs Medal by the American Chemical Society; in 1920 the Chandler Medal by Columbia University, and in 1921 the Perkin



DR WILLIS R WHITNEY

Medal by the American Section of the Society of Chemical Industry.

Dr. Whitney is a member of many societies, among them being the National Academy of Sciences, the American Chemical Society, of which he was president in 1910, the American Electrochemical Society, the American Institute of Mining and Metallurgical Engineers, the American Institute of Electrical Engineers and others. He is a fellow of the American Academy of Arts and Sciences. He holds many important positions, among which are: Member of the United States Naval Consulting Board since 1915, was a member of the Advisory Committee of the United States Bureau of Standards, and is a member of the National Research Council.

At the Medal Day exercises of the Franklin Institute fifteen medals which had been awarded during the institute year were presented to their recipients or representatives of them. The medalists were drawn from four foreign countries as well as from the United States, two coming from England and one each from Canada, Japan and Germany.

JEAN BAPTISTE JOSEPH FOURIER

THE DISTINGUISHED FRENCH MATHEMATICIAN, THE CENTENARY OF WHOSE DEATH WAS CELEBRATED LAST YEAR.

THE PASADENA MEETING OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, JUNE 15–20, 1931

CALIFORNIA offers a most appropriate setting for the first of a new series of summer meetings to be held by the American Association for the Advancement of Science, for of all our forty-eight states it offers the best field for research work in every branch of science

The clear skies and dependable weather of many sections of the state are especially favorable for investigations in astronomy and astrophysics, while the mild and equable temperatures are ideally suited to all types of laboratory work—in physics, in chemistry and in biology.

The fauna and flora of the state are of astonishing richness, and thanks to the great mountains are wonderfully diversified. Not only are characteristic American animals and plants well represented, but many Asiatic types may here be studied in the higher altitudes To the student of marine life the Pacific coast offers a wealth of material a surprisingly large part of which is nowhere else available.

Opportunities for work are one thing, but vision enabling one to see those opportunities and ability to make use of them is quite another thing Vision and resourcefulness have been happily combined with enterprise in making use of the unusual advantages to be found in California

The vigorous and healthy growth of the scientific spirit in the West has been due in no small measure to the emancipation from that conservatism and conventionalism which until rather recently fettered our educational and scientific institutions in the East. But while casting off the fetters of extreme conservatism, the early settlers in California at the same time brought with them the seeds of the essentials of cultural development, which were planted in fertile virgin soil.

This was made possible by the rapid and complete eclipse of the Spanish influence—which was never very strong—before the invasion of the vigorous new blood coming from the East

It may be recalled that the history of modern California began in March, 1848, when the territory was ceded to the United States by Mexico. The acquisition of California was itself to a certain extent the outcome of scientific exploring expeditions headed by General John Charles Frémont the "Pathfinder"—and carried out in 1842, 1843–'44, 1845 and 1846–'47.

In the Constitutional Convention held in 1849, California incorporated into her fundamental law recognition of and provision for a state university.

On January 12, 1777, two Franciscan padres, de la Pena and Murguia, had planted the mission cross at Santa Clara, and in 1851 Santa Clara College was established to save the mission, and also to start a college to meet the growing needs of the times. This institution was chartered as a university on April 28, 1855.

The College of the Pacific was established at Stockton in 1851, Mills College was founded at Oakland in 1852, Contra Costa Academy (later College School) was founded at Oakland in 1853, and in 1855 St. Ignatius College was established in San Francisco

The University of California was established in 1868 as a result of three separate movements—one originating in state action, one in federal action, and one in private initiative.

Following the recognition of the desirability of a state university by the Constitutional Convention in 1849 there had been constant public agitation for making effective provision for such an institution. Federal action began in 1853 when Congress gave the state

46,000 acres of land for a "seminary of learning."

Private action owed its inception to the foresight of the Rev. Henry Durant. In 1853, under the auspices of the Presbytery of San Francisco and of the Congregational Association of Oakland, Mr. Durant opened in Oakland the Contra Costa Academy, but soon changed the name to College School in order to signify that the undertaking was only preparatory to a projected college. In 1855 such an institution was incorporated under the name of the College of California.

The instruction was given in buildings in Oakland, but in 1856 a tract of land five miles to the north was secured, and the college buildings were begun. In 1860 the college was opened.

In 1862 a further impulse was given the movement for a state university by the passage by Congress of the Morrill act for the establishment of an agricultural, mining and mechanical arts college.

In 1867 the three separate forces began working together to one end—the establishment of a University of California. The private enterprise known as the College of California contributed its buildings and four blocks of land in Oakland, together with its 160 acres of land in Berkeley; the federal government the Congressional gift of 150,000 acres of public lands; and the state its property accumulated for the purpose, together with new legislative appropriations. The legislative act creating the University of California was signed by the governor on March 23, 1868, and the new institution opened its doors for instruction in September, 1869.

The University of Southern California was founded at Los Angeles in 1880.

In March, 1881, the legislature of California created the Los Angeles State Normal School. Five acres of ground were donated at the corner of Fifth Street and Grand Avenue—the present site of the Los Angeles City Library—and the corner-stone of the first building was laid on December 17 of that year. Instruction began in August, 1882.

Through legislative action made effective by the governor's signature on July 24, 1919, the grounds, buildings and records of the Los Angeles State Normal School were transferred to the regents of the University of California, and the name of the school was changed to Southern Branch of the University of California. On February 1, 1927, the name of the institution was changed to University of California at Los Angeles. The removal to the present site from North Vermont Avenue took place in August, 1929, and instruction in all departments began in the new buildings on September 23, 1929.

Leland Stanford Junior University, given by Leland Stanford and his wife, Jane Lathrop Stanford, in memory of their son, Leland Stanford, Junior, was established under an act of the California legislature approved on March 9, 1885 The corner-stone of the inner quadrangle was laid on May 14, 1887, and the university was opened to students on October 1, 1891. In connection with the school of biological sciences of this university there is maintained one of the finest marine laboratories in the world, the Hopkins Marine Station, situated on Cabrillo Point at Pacific Grove on Monterey Bay. The first unit of this laboratory, the Alexander Agassiz Laboratory, was built in 1917, and the second unit, the Jacques Loeb Laboratory, was completed in July, 1928. There is also maintained a Food Research Laboratory, which was organized in 1921.

The Lick Observatory, connected with the University of California, was erected in 1887 on Mt. Hamilton at a height of 1,283 meters above sea level. In the same year Pomona College at

Claremont and Occidental College at Los Angeles were established.

The California Institute of Technology was founded at Pasadena in 1891 as a college, a graduate school and an institute for research in science, engineering and the humanities. At the present time this institute includes the Norman Bridge Laboratory of Physics, the gift of the late Dr. Norman Bridge, of Chicago; the High Potential Research Laboratory, provided by the Southern California Edison Company, the Gates Chemical Laboratory, the gift of C. W. and P. G. Gates; the Research Laboratory of Applied Chemistry, the Laboratory of Steam Engineering and Engineering Research, the funds for which were provided in part by Dr. Norman Bridge; the Daniel Guggenheim Aeronautical Laboratory, for which the Daniel Guggenheim Fund provided funds for the construction of the laboratory and for its operation for a period of ten years; the Seismological Research Laboratory, operated jointly by the California Institute and the Carnegie Institution of Washington; Dabney Hall of the Humanities, the gift of Mr. and Mrs. Joseph B. Dabney; and the William B. Kerckhoff Laboratories of the Biological Sciences. Besides these, there is Throop Hall, the central building on the campus, which was the first building of the present group and was the gift of a large number of donors; Culbertson Hall, a beautiful auditorium seating 500 persons, and a marine station at Corono del Mar, near Laguna Beach For work in plant genetics there is a ten acre farm at Arcadia, about five miles from the institute.

In addition, there is the Atheneaum, an autonomous club, the object of which is to provide a place and opportunity for contacts between the distinguished foreign scientists and men of letters temporarily in residence from time to time at the California Institute, the Mt. Wilson Observatory and the Henry E. Huntington Library and Art Gallery, the staffs and graduate students of those institutions, and the patrons and friends of science and education in southern California making up the California Institute associates.

Whittier College, at Whittier, was established in 1901.

The Mt Wilson Observatory, situated on Mt. Wilson near Pasadena, at an altitude of 1,742 meters, was founded in 1904 as an offshoot of the Yerkes Observatory. It is one of the units of the Carnegie Institution of Washington.

The University of Redlands was established at Redlands in 1907.

The Scripps Institution of Oceanography was founded in 1912 through the generosity of Miss Ellen Scripps and others. It is situated at La Jolla. It was originally the Scripps Institution for Biological Research, the name having been changed in October, 1925. This institution is a part of the University of California

Besides these institutions for study and research, California has many others of a more special nature. Especially noteworthy are her museums. The local scientific organizations are numerous and active Some are local, while others are western sections or branches of organizations which are national in scope The scientific establishments maintained by the state must not pass unnoticed. It may be mentioned that California was the first state to protect itself by legislation and quarantine against the introduction of insect pests. In 1881 quarantine laws were passed which were not only sound, but also were novel in their character. Few states to-day have as fine a group of distinguished workers in economic entomology as are to be found in the California Department of Agriculture.

From this brief survey of the growth of the educational and scientific institutions in California it is evident that the

state has been as fortunate in its cultural development as it is in its natural advantages.

South of California lies Mexico, a country which is all too little known to most of our fellow citizens. How many people realize that the University of Mexico was founded in 1554, eighty-two years before the establishment of Harvard?

One of the features of the Pasadena meeting will be the cooperation of the scientific men of our great neighbor to the south. The undersecretary of national education, Señor Don Moises Saenz, will speak on the Mexican educational program, and Dr Manuel Gamio, well known for his work on the ancient temples of San Juan Teotihuacan, has been invited to discuss recent archeological work in Mexico.

Another special feature of the program will be a session in honor of Dr. David Starr Jordan, president emeritus of Leland Stanford Junior University, a most able biologist, an unusually inspiring teacher, and a constructive administrator, who has recently celebrated his eightieth birthday.

An unusually large and interesting series of special symposia and lectures under the leadership of outstanding authorities have been arranged in many different lines of science. The titles of some of these are: major problems in modern oceanographic research; the antiquity of man; high voltage x-ray tubes and their medical and biological possibilities; the physics of crystals; the present status of the problem of nuclear structure; the production of high energy electrical particles; photosynthesis; photochemistry and band spectra; reaction mechanisms and chemical kinetics; quantum mechanics of the chemical bond; the internal structure of stars; earthquake-proof structures; seismological problems; the Colorado River dam and aqueduct; ecological problems of the Pacific coast; and problems in genetics.

A popular lecture will be given each evening at 8:30 in the Greek Theater in Griffith Park, Los Angeles. On Monday, June 15, Dr. Franz Boas, president of the association, professor of anthropology at Columbia, and dean of American anthropologists, will speak on "Race and Progress." On Tuesday Dr. H. D. Arnold, director of research, Bell Telephone Laboratories, New York, will give an experimental lecture entitled "Science Listens." On Wednesday Dr. Arthur L. Day, director of the Geophysical Laboratory of the Carnegie Institution of Washington, will speak on "The Present Status of Seismology." On Thursday Dr. Charles A. Beard, author of "The Rise of American Civilization," "American Party Battles," etc., will speak on "Scientists and History." On Friday there will be held a symposium on "The Impact of Science upon Civilization, Past, Present, and Future" conducted by a historian, an economist and a scientist.

Scientific exhibits will be an important feature of this meeting, and a series of excursions will provide an opportunity for visiting nearby places of special interest under the leadership of competent guides.

As usual, practically all fields of science will be represented in the sessions of the sections and of their related societies. There will be many joint sessions of two or more organizations, and many symposia of invited papers on timely topics. A great many sessions will be devoted to the reading of technical contributions.

With the exceptionally interesting program which has been arranged, and taking place in the inspiring physical and cultural environment of southern California, the Pasadena meeting can not fail to be one of the most successful meetings of the association.

Austin H. Clark

INDEX

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